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Full Name of Author — Nom complet de l'auteur
PERCIVAL ALFRED KURANCHIE

Date of Birth — Date de naissance
DEC 27, 1945

Country of Birth — Lieu de naissance
GHANA

Permanent Address — Résidence fixe
P. O. BOX M 20 ACCRA GHANA WEST AFRICA

Title of Thesis — Titre de la thèse
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PROF T. A. PETERSEN

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OPTIMUM STRATEGIES FOR INCREASED CROP PRODUCTION AND FARM INCOMES IN THE UPPER REGION OF GHANA WITH SPECIAL REFERENCE TO COWPEA

by

© PERCIVAL ALFRED KURANCHIE

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE
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DEPARTMENT OF RURAL ECONOMY

EDMONTON, ALBERTA
FALL, 1979

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Optimum Strategies for Increased Crop Production and Farm Incomes in the Upper Region of Ghana with Special Reference to Cowpea", submitted by Percival Alfred Kuranchie in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Agricultural Economics.

T. A. Petersen
Supervisor

F. V. MacHardy

Leonard Bauer

William Edwards

Melville McMillan

Date Oct 17, 1979

To our Heavenly Father, to Dr. Jean Steckle,
my children and to the memory of Akua NKyaa (my grandmother).

ABSTRACT

The primary objectives of this study were to evolve a set of policy measures necessary to promote increased agricultural output, productivity and income in the Upper Region of Ghana. The policy measures should also promote accelerated production of cowpea without sacrificing increased output of groundnut, millet and sorghum.

The methodology used to accomplish the objectives include postulating the Nerlovian Adjustment-Lag Model in a multiple regression analysis to estimate the cowpea supply function. The instrumental variable technique was used to estimate the model. Optimum-profit farm strategies were designed, using the technique of Linear Programming (LP), for seven representative farms in the region. Various policy measures were simulated through parametric programming and the results of all the optimum strategies compared with those in actual practice. A normative cowpea supply schedule was also estimated from the output vectors generated from the parametric variation of cowpea prices. Finally, quadratic programming was used to design optimum risk-minimization plans for the seven representative farms and the results also compared with plans in actual practice. The Von Hohenbalken finite algorithm was used to solve the quadratic programming problem.

The results of the study have important policy implications for agricultural development in the Upper Region. The results show among other things the following:-

(i) that the potential exists for increased agricultural production and incomes throughout the region even under prevailing farming conditions and technology.

(ii) Farmers' decision-making behaviour is consistent with risk-minimization and not with profit-maximization. Yield risk and uncertainity influence farmers' allocative decisions.

(iii) Under existing production conditions and technology, land resource is the most critical constraint to increased production and farm incomes throughout the region.

(iv) Increased cowpea cultivation under present conditions, is not consistent with resource allocation for optimum profits. Yields or the prices of cowpea would have to improve 57 - 328 per cent (according to the district) before cowpea enterprise appears in the optimum profit farm strategies.

An over-all agricultural development plan in the Upper Region of Ghana that will encompass increased production of cowpea as well as groundnut, millet and sorghum requires a confluence of many policy measures. These measures should emphasize the following (i) the use of improved technology, improved seeds, fertilizers, pest control measures (ii) establishment of viable extension services to diffuse farm management know-how to the farmers (iii) provision of easy credit facilities both in cash and in king to provide farmers with access to the improved inputs. These facilities should be supported by a responsive marketing system equipped with adequate transportation and storage facilities and cash funds to purchase the farm produce from the farmers at prices remunerative enough to encourage them to increase production.

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CHAPTER I

INTRODUCTION

It is perhaps a truism that in a developing country like Ghana the pace of economic development and growth is largely determined by the rate of development of its agricultural sector.[1] A study of industrialization in developing countries by the United Nation's Secretariat stresses the dependence of industrial development on the parallel progress in agriculture and asserts that in some areas the relative neglect of agriculture "has been the cause of serious interruptions in the course of economic development."[2] The economy of Ghana suffered a similiar fate. This occurred long after Arthur Lewis had admonished that "the most certain way to promote industrialization in the Gold Coast (was) to lay the foundations it (required) by taking vigorous measures to raise food production per person in agriculture."[3]

---

[1] Southworth and Johnston (Eds). Agricultural Development and Economic Growth. Ithaca, New York: Cornell University Press, 1969, pp. VII and 3.

[2] United Nations. Processes and Problems in Underdeveloped Countries. New York: United Nations Department of Economic Affairs, 1955, p. 3.

[3] Lewis, W.A. Report on Industrialization of the Gold Coast. Accra: Gold Coast Government, 1953, p. 2.

Agricultural is a significant component of the Ghana economy and therefore any meaningful national development policy needs to incorporate agricultural development and any agricultural development policy needs to be structured within the framework of a total economic development policy. This makes a thorough appreciation of the characteristic features of the economy, an essential prerequisite for determining the appropriate agricultural development policies to pursue in the economy.

This chapter provides a brief discussion of the performance of the Ghanaian economy from the 1960's and highlights the inherent structural problems. The performance of the agricultural sector is then discussed together with past government strategies to promote agricultural development. The chapter concludes with the statement of the problem of the study and its hypotheses.

Recent Performance of the Ghanaian Economy

The economy of Ghana has been plagued by the following major problems since the 1960's: low level of economic growth, balance of payment deficits, inflation and slow change in the structure of the economy. Other problems include rural-urban income gap and rapid urbanization.

Growth of the Economy

The growth rate of the economy since 1960 provides a checkered picture. The high real growth of 7.5 percent (GNP) achieved in 1960 declined to 3.2 percent the following year, rising up to 5.3 percent in 1962 only to fall again to a low of 2.7 percent in 1963.[1] This growth rate was maintained in 1964 but the economy stagnated between 1965-68 with a compound average real growth rate below 0.4 percent.[2] Between 1970-74 however a generally satisfactory growth rate was achieved a compound average rate of 4.5 percent per annum - although this growth did not occur uniformly over the period. For example, the 7 percent real growth rate achieved in 1970 declined sharply to minus 2.7 percent in 1972 as the GNP fell from ¢2029.3 million[3] in 1971 to ¢1978.4 million in 1972.[4] Figures for 1975-78 are not available but preliminary evidence seems to indicate that the economy stagnated and that negative real growth rates might have been experienced.

Underlined by the exponential population growth rate of 2.7 percent and the slow uneven growth of the national product, the level of per capita national income has remained relatively low and stagnant in terms of 1960 prices.[1] Figure 1 and Appendix Table 1 show Index Numbers for Gross National Product and Per Capital Income. Between 1960-64 the real per capita income improved by a meagre 1.4 percent per annum from ¢142 to ¢145 but declined generally below its 1960 level from 1966-69 picking up again to ¢179 by the end of 1974.

---

[1] Central Bureau of Statistics, Economic Survey 1969, Accra: Central Bureau of Statistics, September 1970, p. 15.

[2] ibid. p. 15 and Central Bureau of Statistics, Economic Survey 1972-74, Accra Central Bureau of Statistics, January 1977.

[3] ¢1.00 = $0.36 (U. S.)

[4] ibid. p. 3

Balance of Payments

Ghana enjoyed a relatively respectable foreign exchange reserve of ¢500 million at the time of political independence in 1957. However due largely to an accelerated programme of industrialization and infrastructural development in the period immediately after independence, the foreign reserves were reduced and ceased to be a source of development funds by the end of 1963.[2] By 1962 the foreign reserves had dwindled to ¢150 million; the balance of payment showed a deficit of ¢175 million while there was a total external debt of ¢25.5 million.[3] Since then the country's balance of payment has

---

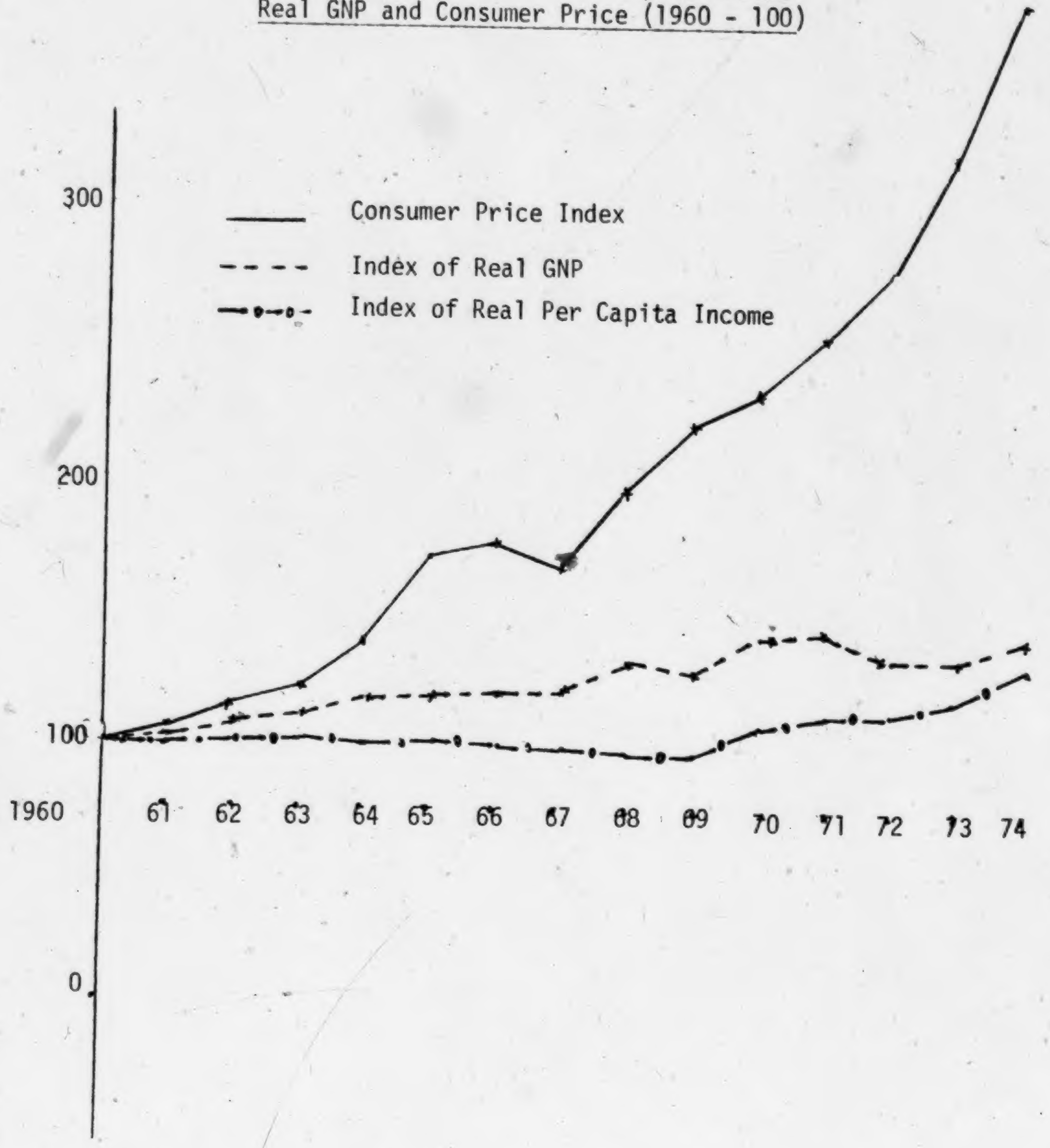
[1] Ministry of Economic Planning. Five-Year Development Plan 1975/76 - 1979/80, Part I. Accra: Ministry of Economic Planning, January 1977, p. 1.

[2] Birmingham, Neustadt and Omaboe. A Study of Contemporary Ghana Vol. 1: The Economy of Ghana. Evanston: Northwestern University Press, 1966, p. 27.

[3] Central Bureau of Statistics. Economic Survey/1968. Accra: Central Bureau of Statistic, 1969.

Figure 1

Index Numbers of Real Per Capita Income
Real GNP and Consumer Price (1960 - 100)



persistently shown deficits while internal and external debts have accumulated. For instance, by the year ending 1969 total government indebtedness stood at ¢1.11 billion comprising ¢506.4 million and ¢604.1 million external and internal debts respectively.[1] By 1974 total indebtedness had increased to ¢1.83 billion. Because of the precarious foreign exchange reserve situation, caused by chronic balance of payment deficits and its negative impact on the flow of investment goods and inputs needed to fuel the economic growth, the balance of payment is aptly dubbed the "Achilles Heel" of the economy.[2]

Several factors have been responsible for the country's balance of payment problems. They include: (i) the fast pace of development set for the country from 1957 to 1966; (ii) the openness of the economy with its high propensity to import; and (iii) the inability of the country's exports (in value terms) to rise - mainly due to adverse terms of trade (especially, low cocoa prices). The latter is illustrated by the fact that whereas the export price index for Ghana (1968 = 100) rose from 107.8 in 1971 to 134 in 1972 and improved further through 1973 to 189.4 by the end of 1974, the import price index (1968 = 100) shot up through the same period to 248.7 by 1974.[1]

---

[1] Central Bureau of Statistics. Economic Survey 1972-74. op. cit. p. 26.

[2] Ministry of Economic Planning. op. cit., p. 2.

In attempts to bring equilibrium to the balance of external payments the external value of the Cedis has been devalued three times between 1967 and 1978 by 30 percent July, 1967, 44 percent December, 1971 (later revised to 26 percent) and 58 percent October, 1978. As well, various forms of import controls, monetary and other fiscal policies have been directed towards holding back domestic demand but these have met with limited success.

The chronic balance of payment deficits appear to be a symptom of a problem with the structure of the economy - a structure which as indicated by Tony Killick "creates a high dependence on imported goods and a low capacity to increase the export earnings."[2] A fundamental solution therefore may well lie in a structural change that will reduce this dependence on imports and increase the export earning potential. Such a solution may reside appropriately in agricultural development.

Inflation

The tendency for the general level of prices to rise in Ghana has persisted since 1960. The Consumer Price Index (CPI) (1960 = 100) rose steadily from 135.7 in 1964 to 167.7 in 1968 - recording an average annual increase of 14 percent over the period. Between 1968-73 it rose by an average annual rate of 27 percent (see Figure 1). While it rose by an average of 124 percent per annum between 1973-76, as the CPI stood at 639 (1960 = 100) at the end of 1976. The situation has since worsened considerably.

---

[1] Central Bureau of Statistics. Economic Survey 1972-74. op. cit., p. 13.

[2] Birmingham, Neustadt and Omaboe. op. cit.

The stagflation being experienced has been caused by a convergence of manifold forces. For example, domestic output has persistently lagged behind increases in domestic demand caused by population growth and the improvement in per capita incomes. This has pushed upwards the general level of prices. But the situation has been compounded by the inability of the economy to generate adequate foreign exchange earnings needed to fill the excess demand gap with imports. The low performance of agriculture has also made a large contribution to the high rate of inflation. Between 60-65 percent of private consumption expenditure is on food of which 50-55 percent is local food stuffs.[1] Indeed local foods together have a weight of 52.1 percent in the cost of living index.[2] The price index of local food stuffs (1960 = 100) rose faster than the cost of living index over the entire period 1960-76 - while the index for local foods stood at 806 in 1976 (1960 = 100) the cost of living index was 639.[1] The cost of living rose at an average rate of 24 percent per annum (1960 = 100) between 1963-76 while the corresponding increase for local foods was 39.8 percent. This indicates that over the period the agricultural sector was unable to supply adequate local food stuffs at stable prices to hold down the rate of inflation.

---

[1] Central Bureau of Statistics. Economic Survey 1969. op. cit. p. 19.

[2] Central Bureau of Statistics. Economic Survey 1972-74. op. cit. p. 127.

Excess growth rate of money supply resulting largely from deficit financing has also contributed immensely to the rate of inflation. For example, from the level of ¢320.3 million at the end of 1971, money supply rose steadily to ¢694.7 million by the end of 1974 - a total increase of 117.1 percent or an average growth rate of 39 percent per annum.[2] The essential feature here is that whereas only the 1972 increase was a direct result of an improvement in the country's foreign reserves[3] all these later increases resulted from deficit financing.

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[1] Central Bureau of Statistics. Consumer Price Index. Accra: Central Bureau of Statistics, 1960-77, various months.

[2] Central Bureau of Statistcs. Economic Survey 1972-74. op. cit., pp. 54 - 55.

[3] Due mainly to favourable world prices for exports and to savings made through import controls.

Unemployment, Urbanization and the Structure of the Economy

Unemployment in Ghana is very much an urban problem.[1] Census estimates of unemployment were 6 percent in both 1960 and 1970.[2] Of this the rates were higher in the urban areas than in the rural areas. Unemployment rates were 10.9 percent and 8.7 percent in 1960 and 1970 respectively in the urban areas and 4.5 percent and 4.8 percent in the same years in the rural areas. The differential rates between urban and rural areas is explained largely by rural-urban migration and the inability of the economy to provide job openings at the same rate as the rate of this migration. One major cause of rural-urban migration is the gap that exists between rural and urban incomes. This is illustrated later in this chapter.

Government policy in the early 1960's was directed towards providing infrastructure and social services to lay the foundations for industrialization and large-scale agricultural production. This policy made it possible for appreciable rate of industrial growth to occur in the early 1960's. However, the pace of industrial expansion could not be sustained and the structure of the economy has since remained unchanged. Appendix Table 2 gives the contributions of the various sectors of the economy to the GDP from 1955-57 to 1975 and illustrates that the economic structure has remained stable over the period with the agricultural sector holding its own as the dominant sector.

---

[1] United Nations. Economic Conditions in Africa, Part II, 1972. New York: United Nations, 1973.
Settlements with population above 5,000 are classified as urban in the population census of 1960 and 1970.

[2] Census Office. 1970 Population Census of Ghana, Vol. II: Accra: Census Office, June 1972.

The significant aspect of the economic structure is that little or only weak linkages exist between the productive sectors. In an input-output analysis conducted in 1960, Szereszewski concludes that most output of the productive sectors goes directly to final uses. The total output of the ten sectors at producer prices was ¢970 million in 1960 and only 8 percent of this was retained as inputs within the productive system. Agriculture sold only 5 percent of its output to other sectors.[1] The situation does not seem to have changed much since 1960. This aspect of the economic structure will have to change to reduce the amount of imported inputs of the productive sectors.

In terms of the often stated policy objectives, namely: the promotion of high and sustained economic growth, increase in per capita income, achievement of equilibrium in the country's external payments, full employment and domestic price stability,[2] it may be concluded that the performance of the Ghanaian economy has not been satisfactory ever since the mid 1960's. While it was growth-oriented in the early 1960's the relatively high growth rates achieved could not be sustained in subsequent years. The balance of payments account has shown chronic deficits while total national indebtedness has mounted through the years; inflation has reached three digits in the past two years while unemployment has not abated. While these have a long history, the situation seems to have worsened particularly during the past five years.

---

[1] Birmingham, Neustadt and Omaboe: Op. cit., p. 66.

[2] Ministry of Economic Planning: Op. cit., p. 17.

These problems have occurred largely because the agricultural sector has not been accorded the proper attention it needs. It is the sector which offers the realistic prospects for a development strategy to revive growth and meet the balance of payment commitments and to lower the rate of inflation. Because of relative neglect the performance of the agricultural sector has been poor and this has constituted the brakes to the overall economic development of the country.

Performance of the Agricultural Sector

A country's agricultural performance should be measured by the extent to which its agricultural development objectives are achieved. However, since Ghana's agricultural objectives are often imprecisely stated, the performance is assessed here in terms of the generally recognized objectives of agricultural development: high sustained growth of output and productivity.

The agricultural sector (including forestry) accounted for an annual average of 57 percent of the country's GDP from 1957-1960. Although its relative contribution has since declined slightly (to 43 percent in 1970-74) it still remains the dominant sector of the Ghanaian economy and will continue to be so in the very distant future. It employs about 56 percent of the total labour force and accounts for some 65-70 percent of the total annual export earnings. The cocoa industry which has been the single major source of foreign exchange since the turn of the century has declined in importance since the 1960's. Its contribution to the GDP had declined from 11 percent in 1960 to 8.5 percent by 1974 while Ghana's share in world cocoa output had also fallen from over 30 percent in the 1950's to below 25 percent by 1975.[1]

Table 1 gives the growth rates of the various components of the agricultural sector from 1960-69 and 1970-74. The table shows that between 1960-69 agricultural GDP grew at an average annual rate of 3 percent - barely above the population growth rate of 2.5 percent during the same period. Fishery production grew at the higher rate of 19.1 percent per annum. Livestock production rose by 3.8 percent while the corresponding rate for crop production (excluding cocoa) was 2 percent, i.e., below the annual population growth rate.

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[1] Central Bureau of Statistics: Economic Survey. op. cit., various years.

Table 1*

Percentage Growth Rate of Agricultural Sector

	1960-69 Average	1970	1971	1972	1973	1974	1970-74 Average
Cocoa		8.6	1.8	5.2	-12.3	-1.9	0.3
Crops (Excluding Cocoa)	2.0	0.7	5.0	2.8	8.7	10.4	5.7
Livestock	3.8	-4.3	25.0	-3.6	16.5	8.1	8.4
Forestry	1.6	0.0	2.8	4.1	8.0	-7.3	1.5
Fishery	19.4	-4.1	8.5	25.5	-31.3	13.8	2.5
Total Agricultural GNP	3.0	7.1	5.1	4.4	1.0	6.2	4.8
Agricultural Export Earnings	0.2	35.3	-33.0	47.0	21.4	35.7	21.3

*Source: Derived from Economic Survey (Various Years), Central Bureau of Statistics, Accra.

Growth was generally high though uneven in the period 1970-74. It was also uneven among the various components of the sector (see Table 2). Major shifts occurred in the growth rate of cocoa output and that of other crops in the period 1970-74. For example, the production of crops (other than cocoa) grew at rates of 8.7 and 10.4 percent in 1973 and 1974 respectively at the expense of cocoa production which declined at the rate of 12.3 and 1.9 percent in those years.

On the whole while growth rate of cocoa production averaged only 0.3 percent per annum between 1970-74 the corresponding rate for the other crops was 7.8 percent. This situation arose because the rise in domestic food prices weakened the competitive position of the cocoa industry and farmers reacted to this by turning to food production in preference to cocoa in many areas. The average annual growth rate in forestry production was only 1.5 percent while that of fisheries was 2.5 percent, i.e., below the national population growth rate of 2.7 percent over the period (1970-74). The average overall growth rate of agricultural GDP was a high 4.8 percent, 0.8 percent higher than the projected rate under the U.N. plan in the Second Development Decade.

The generally satisfactory growth of the agricultural sector in 1970-74 was occasioned by the combined forces of good weather, good domestic food prices and the commission by farmers of more resources into food production in response to a government campaign for self-sufficiency in food and fibre production dubbed "Operation

Table 2*

Growth of Productivity in Agricultural Sector

	1963-67 Average	1969	1970	1971	1972	1973	1974	1969-74 Average
Per Capita GDP Ghana ¢	180	210	224	229	217	225	229	222
Agric. GDP/Capita Agric. Population ¢	138	147	162	162	165	164	169	161
Agric. GDP/Capita Economically Active Agric. Population ¢	351	365	402	415	425	420	435	244
Growth Rates								
Per Capita GDP Ghana	8.6	17.0	6.7	2.2	-5.2	3.7	1.8	3.6
Agric. GDP/Capita Agric. Population	6.8	6.5	10.2	0.0	1.9	-0.01	3.0	3.7
Agric. GDP/Capita Economically Active Agric. Population	8.6	4.0	10.1	3.2	2.4	-1.2	3.6	4.4

*Source: Derived from Economic Survey (Various Years), Central Bureau of Statistics, Accra.

Feed Yourself" launched in 1972. Two successive drought seasons (1975 and 1976) reversed this growth in agricultural production and led to near famine conditions in 1976-77 in many parts of the country.

In a study of 18 indicators of agricultural productivity, growth and stability, Szczepawik concludes that the growth rate of agricultural GDP per capita of the economically active population in agriculture is the best measure of agricultural performance. He indicates that the "optimization of this rate with a given rate of increase in the number of persons actively employed in agriculture is in line with suggestions for making it a central objective of agricultural development strategy and as a pivot for agricultural development plan.[1] With a given rate of change in the size of the agricultural labour force, agriculture's performance is obviously determined by the growth of agricultural GDP. Thus although a generally satisfactory growth rate of agricultural GDP occurred between 1970-74 the crucial question is whether corresponding growth occurred in agricultural GDP per capita of the economically active people in agriculture.

Table 2 and Figures 2 and 3 give agricultural GDP per capita of the agricultural population, agricultural GDP per capita of the economically active population in agriculture, the per capita GDP of Ghana and the growth rates of these parameters for 1963-67 and 1969-74. Table 2 shows that between 1963-67 the average per capita

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[1] Szczepawik, E.F. Agricultural Policies at Different Levels of Development. Rome: F.A.O. of U. N., 1975. p. 107.

Figure 2

Index Numbers for Real GDP Ghana and Real Agricultural GDP Per Capita of Agricultural Population (1968 = 100)

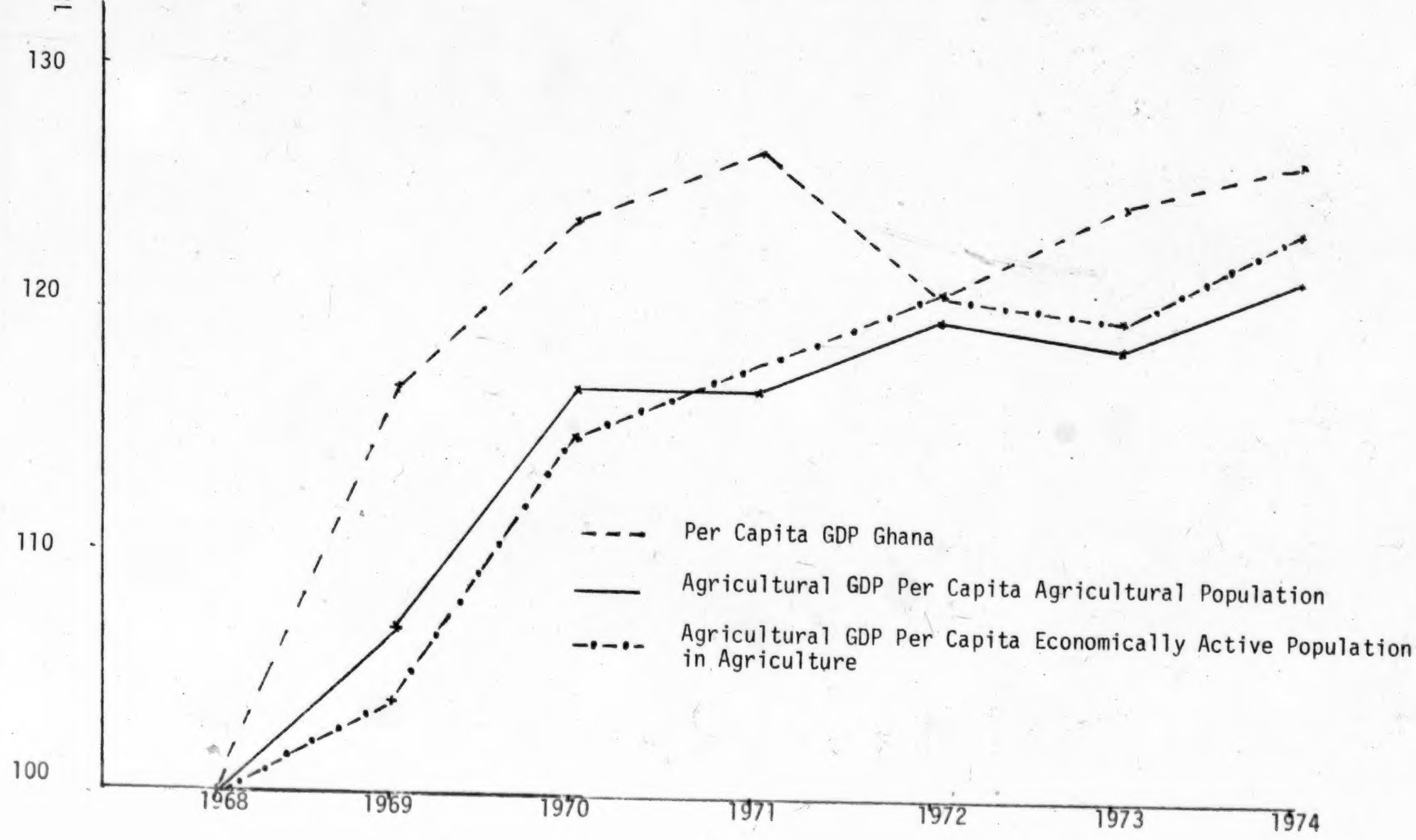
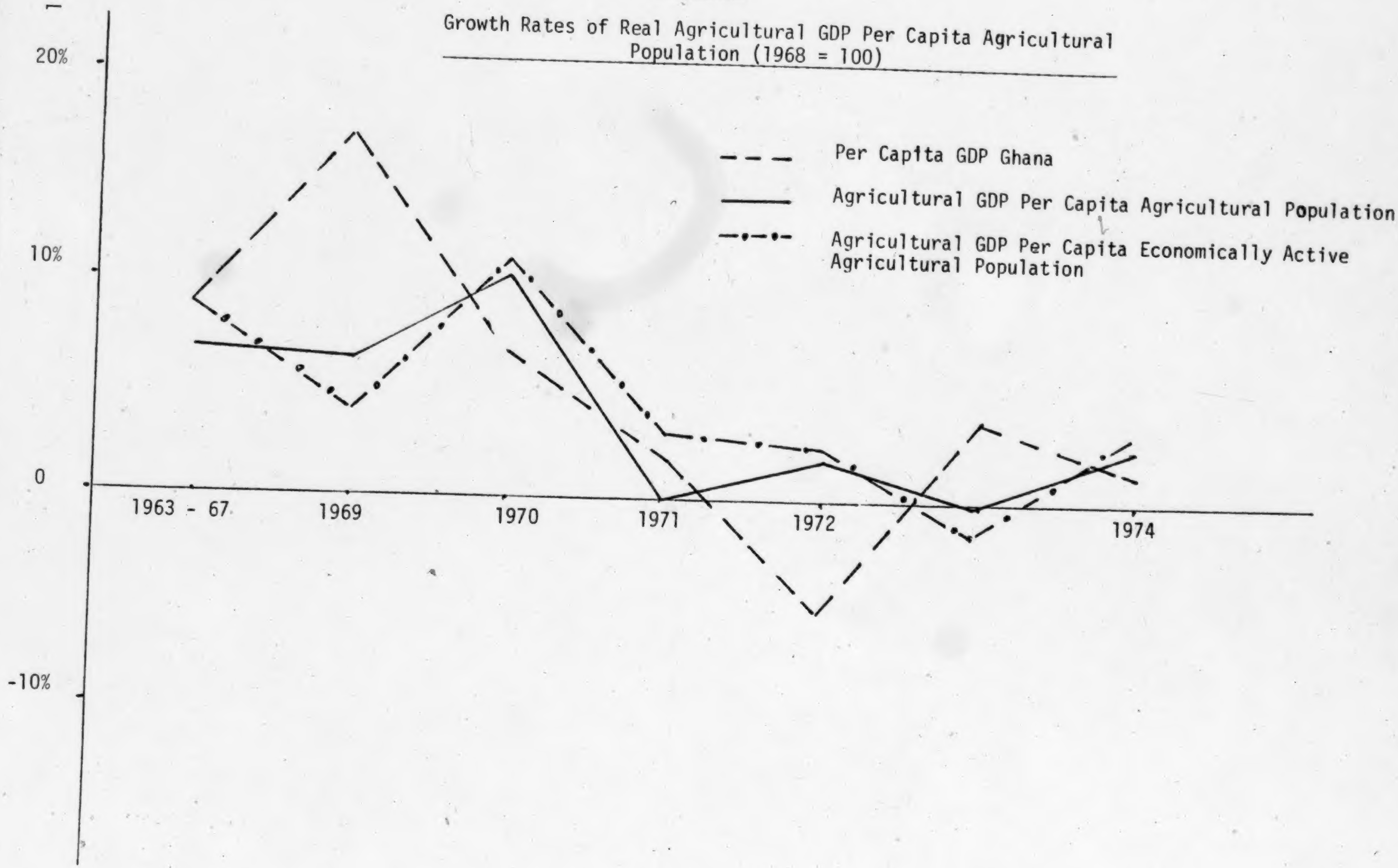


Figure 3

Growth Rates of Real Agricultural GDP Per Capita Agricultural Population (1968 = 100)



GDP of the agricultural population was lower than the national per capita GDP by about 30 percent. This gap generally widened between 1969-74 the average difference being 37 percent over the period. This widening gap provides the incentive for the pervasive rural-urban migration in Ghana. The agricultural GDP per capita of the economically active agricultural population has been considerably higher than the national per capita GDP. It averaged 95 percent higher (annually) between 1963-67 and 85 percent higher between 1969-74. Such a situation should not be surprising if it is considered that agricultural output accounts for 45-52 percent of the national GDP while the economically active agricultural population was 23.5 percent of total (national) population (1970) and grew at 1.8 percent per annum,[1] while the national population growth rate is 2.7 percent.

Table 2 indicates that the growth rate of agricultural productivity (as measured by the growth rate of per capita GDP of economically active agricultural population) was higher in 1963-67 (8.6%) than in 1969-74 (3.7%). In addition to being slow, growth of overall agricultural productivity was unstable between 1969-74 with the percent deviation from the trend being 90. Growth in productivity declined sharply from 10.1 percent to 3.2 percent between 1970-71 and dropped further to 2.1 percent in 1972 declining sharply again to minus 1.2 percent in 1973. Several factors may underline the declining trend.

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[1] Census Office. op. cit.

Agricultural GDP stagnated between 1970-73 while the economically active agricultural population continued to grow at a relatively high[1] rate of 1.8 percent per annum. The stagnation of agricultural GDP is explained by the decline in the cocoa industry during the period due to general deterioation of capital stock (cocoa trees, etc.) in the industry. It is interesting to note that this stagnation occurred in the period when the Operation Feed Yourself campaign was in full force.

Economic Development and Food and Agricultural Policy

McNamara advocates for the broadening of the entire concept of development beyond the "simple goals" of continued growth of gross national product and technological advancement. He asserts that "such economic growth is a necessary condition of development but it is not a sufficient one. The essential condition of development is that it should encompass the basic needs of the two billion people of the developing world: adequate nutrition, meaningful employment, more equitable distribution of income and a decent chance to improve one's lot in life".[2] This is a social welfare concept of development which accepts the realization of the full human potential as an objective of development and characterizes the level of development in those terms.[1] Realization of the full human potential as a development objective is especially important for food and agricultural policies in developing countries where inadequate food intake or malnutrition and its resultant low life expectancy are basic features which constitute the crucial challenges in the development process. In such situations a policy to promote adequate nutrition (in terms of the quantity and quality of food consumption) should become a basic ingredient in an overall development strategy since adequate nutrition is a prerequisite to good health and good health is essential for the achievement of the full human potential.

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[1] "High" because according to Szczepawik (op. cit.) zero growth rate of the economically active agricultural population denotes the point of transition from developing to developed economy.

[2] McNamara, R. Extracts from Speech of R.S. McNamara, President of I.B.R.D. at Closing Session of the Board of Directors. October, 1971. Press Release, No. 76.

It is also a consensus among many economists that economic growth cannot be achieved in an environment of constant food shortages and malnutrition.[2] Burk summarized the reasons for this consensus when she wrote "... food has a social-psychological and political as well as physical significance ... food situation affects people's habits, productivity, ... their social and political attitudes and behavior ... Successful solutions of food problems is an important buttress to economic development, failure can bring it to a halt".[1] There is little wonder, therefore, that the past decade or so has witnessed a strong resurgence of interest and concern by political and economic planners of many developing countries towards agriculture in general and in particular towards the improvement of the nutritional status of their peoples. Such interests and concerns have also been occasioned by:

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[1] Seers, Dudley. "The Meaning of Development" Papers and Reprints. Agricultural and Development Council, Inc., September, 1970.

[2] Southworth and Johnston (Eds), op. cit.

1. The failure of many industrial development projects pursued at the expense of agricultural investments.
2. Rural-urban migration which has led to an exponential growth of the urbanized areas.
3. High population growth.
4. Increases in per capita incomes - all of these have served to intensify the upward movement of food prices in many developing countries.

Ghana is in a similar situation. The country has not been without food and nutrition problems since political independence in 1957. Aylward concludes in a United Nations survey that "both undernutrition and malnutrition exist" in Ghana and that the problem is more pronounced in the Northern and Upper regions which experience periodic food shortages.[1] This is confirmed by Sai who indicates that "clinical shortages of calories" occur in the "hungry pre-harvest seasons" not only in the Northern and Upper regions but also in some parts of the forest zone.[2] The average per capita calorie intake in Ghana is estimated at 2200 per day; nearly 10 percent below the estimated requirement.[3] Similarly the national per capita consumption of protein is estimated at 40 gm. of which animal protein forms only 9 gm per capita per day while the recommended intake is 60-70 gm per capita per day of which some 25 gm should be animal protein.[4]

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[1] Burke and Ezekiel. "Food and Nutrition in Developing Economics" In Southworth and Johnston (Eds) op. cit. p. 328.

In view of the above the solution to the Ghanaian food and nutrition problems appears to lie in an integrated development effort/strategy that will raise substantially the level of food output, raise the purchasing power of the people and promote the intake of the right mix of foods for better nutrition.

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[1] Awlward, Francis. Food and Nutrition. Rome: F.A.O. of U. N. Expanded Programme of Technical Assistance No. 1449, 1961, pp. 3 - 4.

[2] ibid., p. 35.

[3] F.A.O. Land and Water Survey in the Upper and Northern Regions - Ghana, Final Report, Vol. 1, General. Rome: F.A.O. /SF: 31/GHA, 6, 1968.

[4] Sai, T.T. "Nutritional Requirement in Relation to Agricultural Production in Ghana". U.S.A.I.D., 7th Annual Conference Report, 1966, p. 38.

Past government strategies for solving the food and agriculture problems of the country have achieved only limited success. This is demonstrated by the weak performance of the economy in general and the agricultural sector in particular and by the persistence of nutrition problems in Ghana to date.

Between 1957 and 1966 government effort in agricultural development policy mainly stressed direct state involvement in agricultural production. Large scale mechanized farms were established throughout the country while the small scale peasant producer was virtually ignored. However due to political interference and incompetent management, these farms did not live up to expectation. Thus at the height of their "glory" in 1965 when they enjoyed over 65 percent of government's budgetary allocation to the agriculture, these farms contributed only 2 percent of the total agricultural output of the country.

Emphasis shifted from direct state participation in agricultural production with the change of government in 1966. Instead between 1966 and 1975 the large scale private farmer - e.g., the rice farmer in northern Ghana and Dawhenya and the oil palm and sugar cane farmer in the Eastern and Western regions received government priority attention. Again not much attention was given to the small scale farmer! Policy-makers now realize that any effort at solving the country's food and agriculture problems should aim at raising the productivity of the small scale farmer who predominates the agricultural sector and will continue to do so for some time.

The Study Problem

Under the most recent plan of the government for solving the food and agriculture problem, the country has been divided into a number of commodity zones based on the comparative advantage to produce the respective commodities. The strategy under the plan is to provide farmers within each zone with a package of incentives to raise their output. Specifically, certain crops and zones are to be accorded special attention for strategy reasons.

The Regional Development Corporations[1] are encouraged to enter agricultural production along these lines. Furthermore, in the Upper Region of Ghana an agricultural project, Upper Region Agricultural Development Project (URADEP) has been established with loans from the World Bank to administer agricultural development efforts and to ensure sustainable agricultural production and improved farm incomes. URADEP also is to ensure increased production of millet, groundnut, sorghum and cowpea, among other crops, along the lines stated above.

The Navrongo-Bawku area of the Upper Region and cowpea (Vigna ungiculata) are among the priority areas and crops respectively. The importance of Navrongo-Bawku area resides in the fact that it is the country's largest producer of millet, cattle, groundnut and cowpea. Cowpea has been selected for accelerated output to ameliorate the protein supply situation while the livestock and fisheries industries of the country undergo complete rehabilitation. A cowpea programme is therefore under study by the government.

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[1] These are corporate entities established by government, one in each region, to undertake various commercial ventures in order to create employment and equalize economic development between the regions.

The cowpea project includes programmes to increase use of the crop in human consumption. It is an integrated programme partially funded by the International Development Research Centre (I.D.R.C.), Ottawa, Canada. As part of the programme the Nutrition Division of the Ministry of Health (Ghana) will launch a nutrition educational campaign to educate the people on the nutrient qualities of cowpea recipes. The Food Research Institute in collaboration with I.D.R.C., is undertaking research into the various methods of cowpea processing to develop a standardized cowpea flour and new cowpea recipes. The aim is to facilitate cowpea use in the homes, to develop low-priced, high-protein convenience foods from cowpea thereby widening the spectrum of cowpea uses and encouraging increased consumption of the bean for better nutrition.

It is anticipated that the success of the programme will induce an upward shift of the demand for cowpea which will have repercussions at the farm level, the magnitude and direction of which will depend on the supply response. It is appreciated that factors such as the responsiveness of the marketing system - its expansion to handle efficiently a larger flow of commercial supplies of cowpea will determine the extent to which the increased demand of consumers will be reflected in increased incentives to farmers. However the nature and extent of the supply responses will also depend upon the nature of the constraints faced bv the cowpea farmer at the farm level and the extent to which these are eliminated or minimized. The specific constraints involved are largely unknown.

Perhaps more important is the fact that the principal area delineated for increased cowpea production (the Upper Region) and in particular the Navrongo-Bawku area, has also been selected for increased production of groundnut, millet and cattle. In this area (as in most parts of Ghana) cowpea is primarily a subsidiary crop and its cultivation is considered risky and relatively unremunerative.[1] This raises a number of questions including the following:

1. What set of policies will induce increased commercial production of the scale envisaged under the programme.

2. Will such policies induce a shift of farmers productive resources into cowpea at the expense of the crops and livestock which are also of crucial importance of the economy.

3. Will the policies induce changes in the existing farming systems that will in the long run be disadvantageous to the farmer.

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[1] Kuranchie, P.A. "The Relative Economic Position of Cowpea in the Programmes of Farmers in Navrongo-Bawku and Denu-Abor Areas of Ghana" A Report for IDRC Cowpea Network Meeting, Ibadan. Nigeria: November, 1975.

These questions make it imperative that the following be undertaken:

1. Investigation of the supply behaviour of cowpea in response to various technical, institutional and economic stimuli. This may among other things, aid in identifying some of the policy instruments required for the success of the proposed cowpea programme.

2. Investigation of the normative[1] supply responses under various simulated policy alternatives. This will enable the prediction of the effects of alternative policy actions on cowpea production as well as the measurement of any trade-offs between cowpea and the other enterprises under those policies. It will also provide a prescription for achieving the desired optimum resource allocation or farm organization under the various policy alternatives and thus provide guidance to policy makers, extension workers and farmers.

The conditions and techniques of agricultural production in the Upper Region - and in the Navrongo-Bawku area in particular could pose some problems for the proposed cowpea programme. These problems will stem from the existence of a wide range of alternative enterprises or enterprise combinations, the relatively low land-labour ratio and rainfall variability.

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[1] A normative supply response is an estimate of the supply reaction to product price changes in terms of the stated norm as opposed to estimate of the actual supply reaction made by producers to changes in product prices. Some of the norms used in the study include the one that the producer ought to maximize his total profits (see Chapter VI). For a survey of the various value positions see: Johnson, Glenn L., "Philosophic Foundations: Problems, Knowledge and Solution," European Review of Agricultural Economics, Mouton, 1976, Vol. 3-2/3, pp. 207 - 234.

The existence of a wide range of alternative enterprises and the scarcity of resources - particularly land and capital - influences the choice among competing enterprises while the rainfall variability would introduce the element of risk into the choice process. The latter is particularly important for cowpea because of its requirement of certain rainfall conditions for adequate pod formation. This is significant as the subsidiary status of cowpea elsewhere in Ghana (e.g., Denu-Abor area in Volta Region) is attributed to this kind of risk.[1] The problem this poses to the proposed cowpea programme is whether cowpea would be suitable for increased commercial production if farmers in the area select their crops to minimize the risk of income losses. If not, what would be the strategies to pursue in order to minimize the risk associated with cowpea to improve its competitive position and what would be the trade-offs associated with such strategies. Finally the low level of incomes enjoyed by the farmers relative to those of their counterparts elsewhere in the country pre-supposes that any agricultural programme for the area should aim at a substantial rise in the incomes of the farmers.

Very little in-depth research has been carried out in the Upper Region to provide answers to the problems of agricultural development in the area. Lynne carried out a survey to describe the technology of farming and farming systems in the Navrongo-Bawku area of this Region.[1] This study was restrictive in coverage and "positive" in approach. It posed no questions on efficiency of resource use and answered none. The 1970 Agricultural Census Report provides valuable agricultural statistics about the Region. However, the value of this report does not go beyond the statistics it provides although it depicts the prominent contributions of the region to the total agricultural output of Ghana. Kuranchie carried out a study in part of the proposed study area on the relative economic position of cowpea in farmers' programmes. The study revealed that cowpea ranks third in importance after millet and groundnut as source of income and in terms of the subjective rankings accorded to the crops produced. This study was heavily biased towards cowpea and not sufficiently comprehensive. It ignored almost entirely livestock production and failed to examine in any depth the constraints on increased agricultural output and the appropriate policy actions needed to deal with the situation. It is therefore important that a more thorough study be undertaken. The aim of this study is to provide a base for the cowpea programme, to provide answers to the pertinent questions raised above and policy recommendations for increased agricultural production and incomes throughout the Upper Region.

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[1] Kuranchie, P. A. op. cit.

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[1] Lynne, F. "Farming Systems and Practices in the North Mamprusi Area". Accra: Ministry of Agriculture Mimeo, 1949.

[2] Kuranchie, P. A. op. cit.

Objectives of the Study

The study objective is to investigate the economics of crop production (including cowpea) in the Upper Region of Ghana; to assess the potential for increased crop production and farm incomes and provide the general policy recommendations aimed towards realizing such potentials. More specifically the study hopes to:

1. Investigate the pattern and efficiency of resource use by farmers in the Upper Region of Ghana.

2. Estimate cowpea supply responses from the following policy alternatives: price subsidy, credit facilities, and improved technologies and farm management.

3. Given the above policy alternatives, to determine resource allocation for increased crop production, including cowpea under conditions of:

    (a) Risk minimization.

    (b) Profit maximization.

4. To determine the extent of trade-offs, if any, in terms of the output of groundnut and millet under each of the above strategies.

Hypotheses of the Study

Hypothesis One

That the acreage planted to cowpea is directly correlated to the price of cowpea in the previous season.

Hypothesis Two

That acreage planted to cowpea is inversely related to the prices of groundnut, millet and sorghum.

Hypothesis Three

That farmers adjust their cowpea acreage according to rainfall variability.

Hypothesis Four

That farmers' resource allocation (in the study area) is not consistent with profit maximization assumption.

Hypothesis Five

That farmers allocate their resources optimally to minimize risk of crop/income variance.

Hypothesis Six

That under risk minimization conditions cowpea cultivation is not consistent with optimum resource allocation under existing conditions.

Hypothesis Seven

That a deliberate pricing policy (e.g., input or output price subsidy) to improve the competitive position of cowpea will lead to serious decline in the output of groundnut and millet.

CHAPTER II

AGRICULTURAL PRODUCTION IN UPPER REGION OF GHANA

This chapter describes the physical environment of the Upper Region of Ghana and highlights the salient features of its agricultural production - the technology being used, the prevailing farming systems and the region's contribution to the national agricultural output.

The Physical Environment

The Upper Region of Ghana lies between Latitudes 9° 41' and 11° 10' N and Longitudes 9° and 2° 51' W and occupies 10,672 square miles (27,312 km^2) or 11.6 percent of Ghana.[1] It comprises seven administrative districts which also are the agricultural districts with headquarters at Wa, Lawra, Tumu, Navrongo, Sandema, Bolgatanga and Bawku (see Map 1).

Generally, the topography is gently undulating with occasional outcrops of granite rocks. Upland soils which comprise about 50 percent of the region, are shallow with iron concretions developed from the underlying granite rock. Elsewhere the soils are light or

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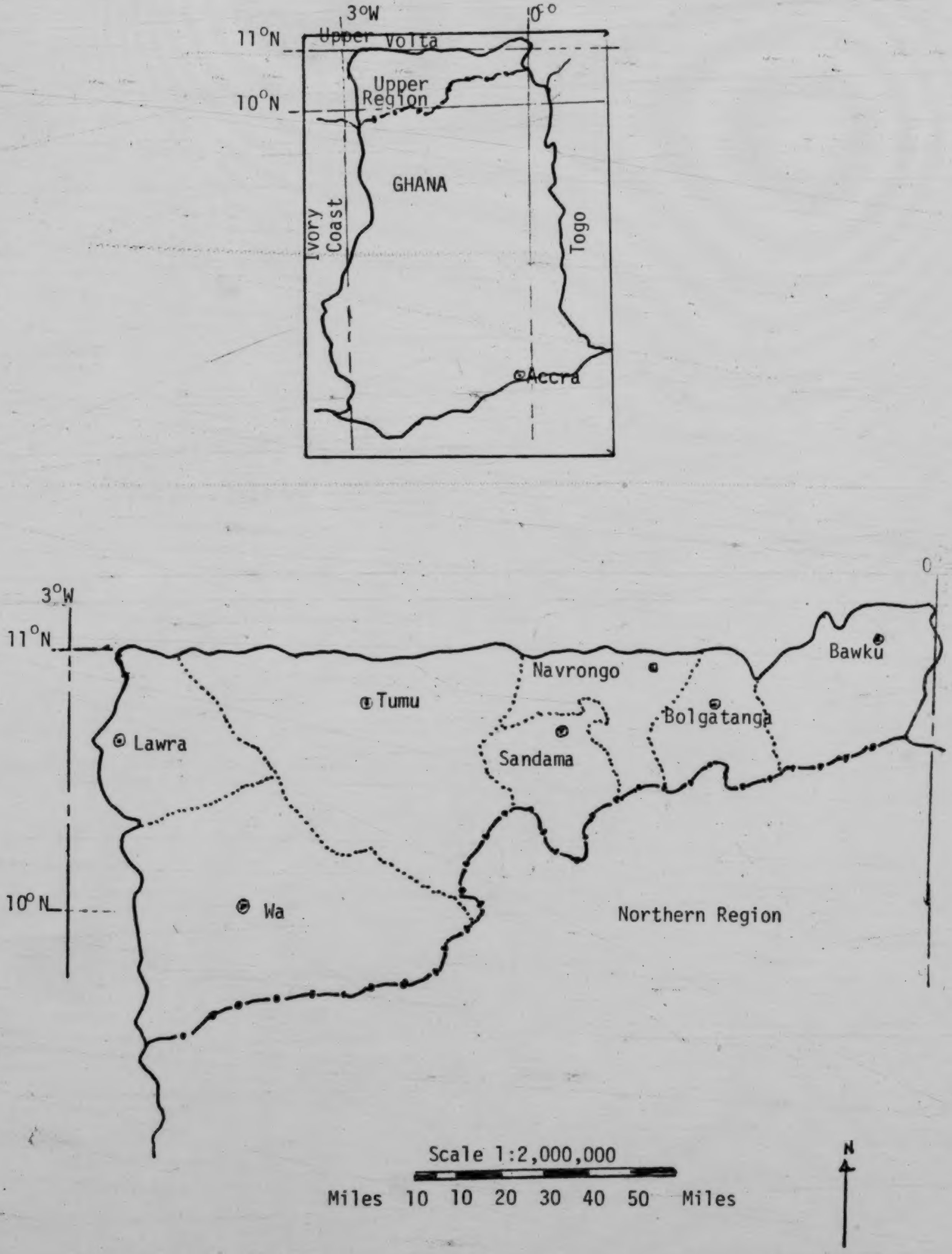
[1] Ghana is 92,000 square miles (235,000 km^2).

Map 1

The Upper Region of Ghana By District



coarse textured but they are moderately deep to deep with accumulation of colluvium on the middle slopes and river valleys.[1]

Rainfall distribution is by no means uniform and decreases eastwards[2] from about 36 inches (1,150 mm) per annum in the northwest (Lawra district) to around 28 inches (950 mm) in the northeast (Bawku district).[3] The driest parts of the region occur in northern Bawku, Navronga and Tumu districts. All the rainfall occurs between April and September with the peak in late August. This period is followed by a dry spell from October to April.[4] Daily temperatures during the rainy season ranges from 25°C around August to 32°C in April. However during the dry harmattan seasons, temperatures can reach 45°C during the day while night temperatures may fall below 15°C.[5]

The Upper Region is located within the Guinea Savanna Zone where the natural vegetation is savanna woodland. The repeated cultivation and grazing with the accompanying exposure to the elements has, however, reduced most parts of the region to open parkland where only trees of economic value persist.[1]

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[1] World Bank. Appraisal of Upper Region Agricultural Development Project Ghana Report. Report No. 106a - GH, June, 1976.

[2] The east-west variation in rainfall gives rise to differences in the types of crops produced. The wetter north-west produces maize and yams which are unsuitable in the low rainfall areas to the east.

[3] Ibid.

[4] Because of the single rainfall season there is only one cropping season in a year except where dry season farming is practiced in the valley bottoms.

[5] Ibid.

Total regional population for 1975 was estimated at 928,000 based on the annual growth rate of 1.4 percent between 1960-70 recorded in the 1970 Population Census.[2] This growth rate was among the lowest in the regions of Ghana and is explained by high infant mortality rate and southward emigration of the youth in search for jobs. Population distribution within the region is uneven. With the exception of the relatively fertile river valleys which are virtually uninhabited due to the onchocerciasis disease (river blindness), population distribution is closely associated with soil fertility. Thus while in parts of the Wa and Lawra districts population densities exceed 50 per km^2, elsewhere in the western and central parts of the region population density is below five per km^2. Population density increases eastwards from Tumu approaching 100 per km^2 in Bolgatanga and Bawku districts which are among the most densely populated areas in Ghana.[3] The differential population pressures on the land have resulted in differing farming practices within the region.

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[1] Predominant among these are Parkia fili coidia (dawa dawa) and Butryosperum parkii (Shea butter).

[2] Census Office. op. cit.

[3] Ibid.

Agricultural Production

It is generally accepted that the major operators in the agricultural sector are the small-scale farmers[1] and that they will continue to dominate for a long time to come.[2] It is only in rice production and perhaps in sugar-cane production where large scale producers have recently started to make an impact, contributing about 25 percent of Ghana's total rice output in 1974.[3]

The 1974 Agricultural Census estimated there was a total of 859,191 holders in Ghana of which 857,000 (99.8 percent) were small-scale holders[4] with an average size of holding of 4.3 acres or 1.7

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[1] Various definitions are given for a small-scale farmer in Ghana but the 1974 Agricultural Census includes as large scale holders institutions, cooperatives and individual private holders with 50 acres and above of crops other than cocoa; or over 2,000 birds; 100 heads of cattle in Northern and Upper Regions and 50 heads elsewhere in Ghana; over 200 heads of goats or sheep and over 40 pigs. All farmers with smaller holdings are classified as small scale. See Current Agricultural Statistics, 1974, Ministry of Agriculture, Planning Division. Accra: May, 1975, p. 60.

[2] The Seven-Year Development Plan 1963/64-1969/70 observes that "the small scale farmer with his hoe and cutlass has virtually created Ghana as she is today." The Seven-Year Development Plan 1963/64-1969/70, Office of the Planning Commission Accra, p. 54. Also see The Five-Year Development Plan 1975/76-1979/80, Part II. January, 1977.

[3] Ministry of Agriculture. Current Agricultural Statistics, 1974. May, 1975.

[4] A holding here refers "to a parcel or parcels of land wholly or partly used for agricultural production the day-to-day operation of which one man is responsible. For the sake of simplicity the holder is referred to as a farmer." See Brimingham et al., op. cit., p. 225.

hectares.[1] Cumulative figures on acreage classification were not given in the 1974 census report but the corresponding figures in the 1970 report indicate that 30.5 percent of the holders cultivated less than 2.0 acres, 54.7 percent less than four acres and 81.9 percent less than 10 acres while only 18.1 percent cultivated 10 acres or more.[2] Furthermore, the holdings of the average farmer comprises 2.7 farms or fields with an average size of two acres each. These farms severally form the basic productive units for the holder. It is obvious therefore that on the whole farm sizes are very small. This raises many fundamental issues as to the appropriate strategy for agricultural development.[3]

An estimated 10-15 percent of the total arable land in the Upper Region is under cultivation. This apparently low level of land utilization is explained by the fact that large tracts of land, especially in the river valleys, are uninhabited because of the prevalence of Onchocarciasis (River Blindness) and Trypanosomiasis

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[1] Ministry of Agriculture. Current Agricultural Statistics, 1974, p. 9.

[2] Ministry of Agriculture, Economics and Planning Division. Ghana Sample Census of Agriculture, 1970 Vol. 1. Accra: Ministry of Agriculture, March, 1971.

[3] Kenneth L. Bachman and Raymond P. Christensen discuss the problems posed by small farm sizes in agricultural development. See "The Economics of Farm Size", Bachman and Christensen in Agricultural Development and Economic Growth, ed., Southworth & Johnston, op. cit., pp. 234 - 266.

(Sleeping Sickness). In addition many parts of the region are rocky and unsuitable for cultivation. Small-scale holders in the region numbered 106,000, 12.4 precent of the national total according to the 1974 Agricultural Census,[1] and cultivated an average of 5.7 acres (2.3 hectares). This indicates that the average size of holding in the region is 32.5 percent larger than the national average. Holdings average 9.3 acres (3.9 hectares) in the Wa-Lawra-Tumu districts and average 6.9 acres in the Bawku districts. This is larger than in the Navrongo and Bolgatanga districts where average sizes of holding were estimated to be 3.6 acres (1.05 hectares) and 3.3 acres (1.3 hectares) respectively.

Farming Systems

The technology employed and the pattern of agriculture is fairly consistent throughout the region although production systems vary somewhat according to population pressure. The land is cleared of the grass vegetation or stubbles of previous crops by means of burning.[2] More recently however the use of tractor power for ploughing, ridging and harrowing is becoming more common. Nonetheless ploughing and mound-making is typically done by means of the hoe, over most of the region although in the east - particularly in the Bawku district bullock ploughing is wide spread.

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[1] The corresponding figure for large-scale holders is not available.

[2] Nye and Stephens argue that the method is one sure and fast way of returning the minerals in the vegetation back into the soil for the benefit of subsequent crops and it kills stubborn weed seeds, pests, and disease carriers in the soil. See P.H. Nye and D. Stephen in Agriculture and Land Use in Ghana, ed. J. Brian Wills. Oxford: Oxford University Press, 1962.

Seeding is done during the first rains in April-May by broadcasting or "nibbling" seeds into the soil with the aid of sticks. After seeding, crop maintenance comprises mainly weeding and mound or ridge repairs. Spraying of crops against insects and disease pests is virtually non-existent except for crops like tobacco and cotton (where they occur). Crops are harvested with a sickle or cutlass and the grains stored in large earthen wares or wooden silos. Stored grain is protected from weevil and other pests with wood ash and smoke.

Intercropping is very widely practiced throughout the region as elsewhere in the country. Intercropping, analogous to horizontal diversification on a given unit of land, has many advantages. It provides insurance against total crop losses due to pest and disease infestation and even against drought since the array of crops occurring within the mix will usually have differential susceptibility to various emergencies. However Norman argues that the yields of individual crops in the mix are depressed by reason of low crop densities and the effects of competition for light and soil nutrients.[1]

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[1] Norman, O.W. "Intercropping of Annual Crops Under Indigenous Conditions in Northern Parts of Nigeria". A Paper Presented at the Conference on Factors of Agriculture Growth in West Africa. Accra: University of Ghana, March 27 - April 2, 1971.

Pure cropping is also widely practised in the region. The 1974 Agricultural Census Report provides evidence of the importance of pure cropping in the region. The report indicates that 49 percent, 44 percent, 57 percent, 42 percent and 54 percent respectively of maize, millet, sorghum, yam and groundnut acres cultivated throughout the region were in pure stands.[1]

L.A.R.C. reports that the crop rotation is also more widespread in the Upper Region than elsewhere in Ghana although crop sequences in the various rotations differs among farmers and districts.[2] Adherence to crop rotation appears to be a reaction to the single rainfall season since together with intercropping, crop rotation enables farmers to increase the total number of crops they can cultivate within the short growing season.

Variation in the population density affects the farming systems practiced. High population density is associated with intensive land utilization. In the Tumu district where the pressure on land is low, the system of land rotation called bush fallow is practiced. Under this system, land is cultivated continuously for two to four years and abandoned for a period of five to ten years to regenerate its fertility as it reverts to fallow vegetation. Settled or permanent cropping in this district is virtually non-existent. Elsewhere in the west (Wa, Lawra districts) and the east (Navrongo, Bolgatanga and Bawku districts) where the pressure on land is high because of high population density, settled farming or permanent cropping of lands immediately surrounding the homesteads is the rule. These farms, referred to as "compound farms", constitute the main distinctive feature of the farming system of the western and eastern parts of the Upper Region from those elsewhere in the country. Compound farms are usually carefully cultivated to cater to the subsistence requirements of the farm families and are usually planted to food grains and vegetables. They are often communally cultivated by all the families in the compound and the produce stored in a common granary. Soil fertility is maintained by the use of household refuse, livestock manure and the deliberate inclusion of legumes in the rotation. In addition to compound lands, other lands lying at various distances from the homesteads are extensively cultivated, as in the Tumu district and other parts of Ghana. Such farms are usually planted to cash crops or other crops to supplement the produce from the compound farms.

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[1] Ministry of Agriculture. op. cit.

[2] Land Administration Research Centre (LARC). Land Use, Agricultural Production, Land Tenure and Administration, CSIR North-East Savanna Project. Kumasi: LARC, University of Science and Technology, October, 1977 and monograph.

Table 3 gives the percentages of holdings growing the principal crops in the region in 1974 and indicates that 70-95 percent of the cultivated land was planted to food crops. Early and late millet and sorghum were the most important crops. Being the staple food of the people, they occurred with the most frequency on the holdings.[1]

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[1] Millet takes priority over sorghum as a staple food. The latter is used chiefly for brewing *pito* a local household beverage.

Table 3*

Percentage of Holdings Growing Principal Crops In Upper Region, 1974 - By District

	Crops[1]					
Districts	Millet	Sorghum	Rice	Yams	Groundnut	Maize
Wa-Lawra-Tumu	97.0	90.5	12.3	69.0	69.0	
Navrongo[2]	97.8	91.4	32.3	--		48.2
Bolgatanga	97.8	81.4	12.3	--	92.1	
Bawku	90.5	96.1	1.6	--		30.0
Total Region	96.0	89.0	17.3	12.0	75.4	24.0

[1] Figures for cowpea and bambara beans are not available.

[2] Includes Sandama District.

*SOURCE: Compiled from Current Agricultural Statistics, 1974, op. cit.

Yams and maize, however, supercede millet, particularly early millet in the wetter western sector of the region. Groundnuts, cowpea and bambara beans are the leading cash crops for the small scale holders of the region as well as being important dietary constituents of the people. Rice cultivation has also attracted relatively large scale farmers to the river valleys while efforts are continuing to promote cotton, kenaf and tobacco as cash crops.

Another important aspect of the agricultural production in Upper Region is the potential and current contributions of its livestock industry. Mixed farming is widely practiced throughout the region and in many instances livestock production is complementary with crop production. It is estimated that over one-third of the farmers in the region own cattle; over two-thirds own sheep or goats while nine-tenths have poultry although the livestock numbers per holder vary widely.[1]

Livestock is kept for multiple purposes. They provide a source of meat for both domestic consumption and for sale; they are a store of wealth easily convertible to cash for financing purchased inputs for the other agricultural activities and for meeting social and other contingencies. Cattle ownership is a status symbol in the society, as well as a source of assets for meeting the "bride price" in marriages. Cattle are also an important source of draft power for cultivation and in many cases for haulage. As well, and especially in the eastern parts of the region, livestock is specifically corralled to provide the much needed farm yard manure to fertilize the compound farms. Cow dung is also sometimes used as a source of fuel. On the other hand livestock utilize crop residues after harvest. While great potential does exist for improved livestock production in the area, some of the basic problems the industry faces include inadequacy of assured supplies of feed and water the year round, poor genetic stock and deficient husbandry practices.

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[1] Ministry of Agriculture. op. cit.

Agricultural Surplus in the Upper Region

For the agricultural sector to contribute to the overall development of an economy, it is imperative that a high and sustainable marketed surplus be generated in that sector.[1] This marketed surplus provides the vehicle through which agriculture makes its contribution in the development process when it (surplus) is tapped to finance industrial and infrastructural investments.

Contrary to opinions expressed by some commentators, available statistics indicate that substantial food surpluses are produced in the region in normal crop years.[1] This is especially true with groundnuts, cowpea and even millet and sorghum which are the major staples in the area. It is true, however that agricultural production is perhaps more precarious in the region than elsewhere in Ghana because of the relatively low and usually uncertain rainfall conditions. In years of poor rainfall, food deficits do occur and, in extreme cases, famine or near famine situations may arise when many farmers exhaust their food stores and even consume the seeds stored for the next planting season. A sensitive balance of food production may therefore be said to exist in which many families are susceptible to periodic food shortages as a result of poor rainfall conditions. This by no means indicates that farmers in the Region are purely subsistence producers. Table 4 gives a food balance sheet for 1974 (a normal crop year in terms of yields). Marketed surpluses are usually transported southwards. The table shows that the region accounted for 7500 and 9400 tons of cowpea and groundnut marketed in the country that year. It also contributed 3400, 8900 and 3000 tons of millet, sorghum and rice respectively.

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[1] See William H. Nicholls. "An 'Agricultural Surplus' As a Factor in Economic Development" in Readings in the Economics of Agriculture. Karl A. Fox and G. Gale Johnson (Eds) Homewood, Illinois: Richard D. Irwin, 1969, pp. 386 - 419.

The above account may lead one to conclude that production in the region is a composite development problem. Solution may require the consideration of the following: (a) providing a stable pro-

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[1] L.A.R.C., *op. cit.*, p. 8.

Table 4 *

Regional Food Balance Sheet, 1974

	Shortage Losses	Seed Retention	Family Consumption	Gross Production	Shortage Losses	Seed Retention	Family Consumption	Surplus Production
	%	kg/ha	kg			'000 Tons		
Millet	10	3	500	73.8	7.4	0.5	62.5	3.4
Sorghum	12	4	350	60.5	7.3	0.6	43.7	8.9
Maize	15	12	90	14.5	2.2	0.4	11.3	0.6
Rice	2	60	60	17.0	0.3	1.2	7.5	3.0
Ground-nuts	2	35	50	17.5	0.4	1.4	6.3	9.4
Yams	20	1,500	90	39.8	8.0	20.3	11.5	--
Cowpeas	15	10	20	12.9	1.9	1.0	2.5	7.5
Bambara Beans	10	25	10	3.8	0.4	0.4	1.3	1.7

*SOURCE: Appraisal of Upper Region Agricultural Development Ghana, Report No. 106a-GH, World Bank Annex 4, Table 4.

- duction environment by way of irrigation facilities, dams/dug out wells to improve availability of water for cultivation and livestock; (b). providing improved planting materials and drought resistant varieties, improved breed of livestock, fertilizers and pesticides to increase yields.

CHAPTER III

ORGANIZATION OF THE STUDY

This chapter presents the general methodology used to accomplish the objectives of the study. More specifically, it describes the procedures used to collect data in the sample survey and mentions the analytical tools used to analyze the data in the study.

The General Approach

The hypotheses of this study are tested with the results of the empirical analyses undertaken. Hypotheses 1, 2 and 3 are tested by estimating cowpea supply response in a multiple regression analysis. The results obtained are verified through a normative cowpea supply response analysis. The latter is performed with data generated from parametric programming. Hypothesis 4 is tested from the results of linear programming analysis which is used to generate optimum profit farm plans for representative farms in the Upper Region. Hypotheses 5 and 6 are tested from (risk) quadratic programming analysis. Finally the results from parametric programming analysis provides the test for Hypothesis 7.

Sources of Data

Both primary and secondary data are used in the empirical analyses carried out in the study. The time-series data on crop acreages and prices and rainfall were obtained from secondary sources. Publications of the Ministry of Agriculture and the Central Bureau of Statistics were the prinicipal sources of crop production (acreage) and price data. Rainfall statistics were obtained from the annual reports and files of the Meteorological Services Department. The primary data used in the study were, however, obtained from a sampled survey of farmers in the Upper Region. The data from the survey covered the entire 1978 farming season.

Sampling Procedure

The Upper Region has seven agricultural districts which coincide with the political administrative districts. For the purposes of their agricultural census of 1970 and annual sample census of agriculture, the Ministry of Agriculture has divided the region into 458 enumeration areas. Each enumeration area comprises a number of villages or hamlets. The Ministry maintains and reviews the names of all the villages and the farm holders in each of the enumeration areas.

In order to facilitate the conduct of the survey for the study, the sample frame of the Ministry of Agriculture was used. The records of all the enumeration areas, villages and farm holders were obtained from the Regional Agricultural Office in Bolgatanga and two stage sampling procedure used to select the farms for the study. In the first stage, 35 (7.7%) of the 453 enumeration areas were selected through a random (probability) sampling. The 35 enumeration areas covered the entire region and were distributed among the district according to their numbers of holders. The distribution was made as follows: Lawra, Tumu, and Sandama districts in the western sector, 5, 5, 2 and 2 respectively. In the Navrongo, Bolgatanga and Bawku districts the enumeration areas selected were 5, 7 and 9 respectively. The farm holders were selected in second stage sample. Ten holders were randomly selected from the lists of holders in each of the 35 enumeration areas. A total of 350 farm holders were therefore selected for the study. This comprised 0.11 percent[1] of the total number of farm holders in the region.

Data Collection

The actual sample survey was conducted between September 1978 and February 1979. It was carried out in two stages with the aid of questionnaires. The first stage involved all the 350 selected holders. An open-ended questionnaire was used to obtain information about family sizes, farmers' resource constraints, problems with acquision of further resources, and farming programmes. The second stage of the survey involved a sub-sample of 100 holders selected through random probability sampling from the original 350 holders. The sub-sample was the subject of a more intensive study to obtain further data on farm operations. Details of input expenditure on various enterprises were studied and measurements of farm sizes and crop yields were taken to derive input-output coefficients for the crop enterprises. The questionnaires used in the survey are provided in the appendix.

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[1] The smallness of this sample size is explained by the meagreness of the resources (including time) available for the study.

The questionnaires were administered to the farmers by 35 Farm Enumerators loaned from the Ministry of Agriculture Economics and Planning Division Upper Region. The farm enumerators are field staff of the Economics and Planning Division employed and trained specifically to collect farm level data and undertake agricultural census for the Division. The arrangement to assign the 35 farm enumerators to the survey was made between the Food Research Institute in Accra and the Ministry of Agriculture. Each farm enumerator was assigned to one enumeration area to administer the questionnaires to 10 holders in the first stage and to 2 - 5 holders in the second stage of the survey. The enumerators were supervised throughout the survey by senior technical officers of the Ministry of Agriculture, in charge of the respective districts, a senior technical officer from the Food Research Institute who was also the survey co-ordinator and by the author.

Immediate training of the enumerators for the survey included a week's briefing by the author and the co-ordinator and a pretesting of the questionnaires with the enumerators actively participating. There were a number of advantages in using the services of the enumerators in the survey. They were already familiar with the nature and difficulties of the type of survey; familiar with the farmers and spoke their local languages. The farmers were therefore able to respond readily, confidently and truthfully to the questionnaires.

Analytical Models

The analytical tools used in the study are multiple regression analysis, linear programming, with parametrics and quadratic programming. The Nerlovian Adjustment Lag model is formulated in the regression analysis and estimated with the instrumental variable procedure. Chapter IV provides a description of the model and the solution procedure used. The use of linear programming technique is discussed in Chapter VI while an account of the quadratic programming technique is given in Chapter VII.

CHAPTER IV

CHARACTERISTICS OF SAMPLE AND FARMER RESOURCE SUPPLY

This chapter discusses the characteristics of the sample farmers used in the study, their resource supply situations including the values of their capital stock in agriculture. The chapter closes with discussion of farmers' crop holdings, the returns from crop production and concluding remarks.

Literacy, Age and Non-Farm Employment

Illiteracy and old age are often associated with tendency to resist change and innovation.[1] Hence a sector of an economy which is dominated by the aged and the illiterate risks stagnation unless it becomes attractive to the youth and the educated. This is a problem of the agricultural sector in Ghana.

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[1] See Brown, C.K. Some Problems of Investment and Innovation Confronting the Ghanian Food Crop Farmer. Technical Publication Series, No. 24, Isser, University of Ghana, Legon, 1972, p. 30 and Hoffar, C.R. 'Acceptance of Approved Farming Practices Among Farmers of Dutch Decent' in Michigan Agricultural Experimental Station, Special Bull. 316, p. 31.

Appendix Tables 3 and 4 give the educational background and the age distribution of the farmers studied. Ninety-seven percent of the farmers had had no formal education at all while only 1 and 2 percent had had primary and above primary education respectively. The average age of the farmers in the sample was 45 years but farmers in the Lawra district were older on the average, than their counterparts elsewhere in the region (See Appendix Table 4). The largest percentage (52.6%) of the farmers were above 45 years of age; 34.5 percent were between 36-45 years while only 12.9 percent were 35 years or younger. These findings are consistent with other results obtained elsewhere in Ghana and emphasizes the need to make farming and rural life attractive to the youth.[1]

Although the Upper Region is predominantly an agricultural community, many farmers engage in non-farm activities particularly during the long dry season of September - April to supplement their incomes and to stave off open unemployment. About 14 percent of the farmers studied had non-farm employment. The phenomenon was however more pronounced in the Bolgatanga district (see Appendix Table 3) where 49% of the farmers engaged in other renumerative activities than farming sometime during the year. This should not be surprising since Bolgatanga (the district capital) is also the Regional head-quarters and the largest market in the region. Avenues for non-farm employment are therefore higher there in the government sector while its market for handicrafts is the largest in the region. The popular non-farm employments included trading, handicraft, security guard and enrollment as casual labourer in government offices and construction sites. Incomes from these sources ranged from ¢200.00 to ¢7,000.00 per annum per farmer in the sample and averaged ¢215.00. It should be noted from Appendix Table 3 that throughout the region taking on a non-farm employment is not a very widespread phenomenon. It is confined mainly to Bolgatanga district and to a lesser extent Lawra district. For example, in the Tumu district none of the farmers had any part-time off farm occupation while in the Sandama, Wa and the Navrongo districts percentage of farmers with such employment were only 5, 4, and 2 respectively see Appendix Table 3.

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[1] See Ross E. Bigelow, Farms in Southern Savanna in Ghana. Abor., Department of Geography Michigan State University, PhD Thesis, 1973. (Unpublished)

Resources Available to Farmers

Land Resource

Under the traditional farming conditions prevailing in the Upper Region of Ghana land and labour are the chief factor inputs. Consequently, the quality (in terms of inherent fertility) and quantity (the size) of the land resource available to the farmer largely determines the farm output and income. Land therefore becomes a measure of income, wealth and a status symbol.

Ninety-eight percent of the farmers studied were natives of their respective districts who cultivated ancestral lands and therefore experienced no tenure problems. These farmers possessed usufructary rights to their lands which are determined by historical and cultural factors; are highly valued and scarcely marketable.[1] As a result, especially in the more populous districts of Bawku and Lawra, it is becoming increasingly difficult for new farmers to acquire additional lands except in places remote from the villages.

Table 5 gives the average size of available land per farmer in the sample by districts and the utilization of this resource from 1975-78.[2] The acreage of land available per holder is closely associated with population density. Table 5 indicates that farmers in the Bolgatanga and Navrongo districts had the smallest average land sizes of 4.1 and 12.2 acres per farmer respectively. Those in the Wa and Tumu districts possessed the largest land areas averaging 37.2 and 31.8 acres per farmer respectively. Average available land per holder in the Sandama, Lawra and Bawku districts were 20.6, 22.1 and 16.3 acres respectively (see Table 5). The total sample average was estimated at 15.6 acres per holder.

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[1] These include the right to cultivate as one pleases to lease to others and to pledge against loans although less common, but do not include the right to sell. See Ollenu Amaa (1971) "Problems of Land Administration and Development in Ghana." Paper presented at a seminar on Land Problems and Development in Ghana. Kumasi: Department of Land Economics, University of Science and Technology. October, 1971.

[2] Availability here denotes the right over cultivation without let or hinderance.

Table 5*

TOTAL AVAILABLE LAND PER HOLDER & UTILIZATION

1975 - 1978 (ACRES)

	TOTAL AVAILABLE ACRES	UTILIZATION								
		1978		1977		1976		1975		1975-78
WEST		ACRES	(%)	ACRES	(%)	ACRES	(%)	ACRES	(%)	AVE. %
WA	37.2	9.3	(25)	8.0	(22)	7.2	(19)	7.6	(20)	21.5
LAWRA	22.1	12.9	(58)	10.2	(46)	9.0	(41)	8.6	(39)	46.0
TUMU	31.8	18.9	(59)	16.6	(52)	16.6	(52)	16.4	(52)	53.8
EAST										
SANDAMA	20.6	3.4	(17)	3.4	(17)	4.1	(20)	5.2	(25)	19.8
NAVRONGO	12.2	3.5	(30)	3.5	(29)	3.7	(30)	3.7	(30)	29.8
BOLGATANGA	4.1	2.7	(66)	2.1	(51)	2.1	(51)	2.1	(51)	54.8
BAWKU	16.3	5.2	(32)	8.6	(53)	8.6	(53)	8.1	(50)	47.0
AVERAGE										
TOTAL SAMPLE	15.6	8.7	(56)	5.6	(36)	5.6	(36)	5.5	(35)	40.8

*SOURCE: COMPILED FROM SURVEY DATA.

While farm holdings are in general, larger than the national average, they are by no means uniform throughout the region.

Table 5 also provides information on the size of holdings per farmer for 1975-78. Very small holdings occurred in the Bolgatanga, Navrongo and Sandama districts where the sizes were 2.7, 3.5 and 3.5 acres per farmer respectively in 1978. Farmers in the Tumu and Lawra districts had the largest holdings in the region. The relative sizes of holding did not correspond to the relative sizes of the land resource available to the farmers (see Table 5). This seems to indicate that some other factors are more constraining than land in some of the districts, for example, in the Sandama and Wa districts where only 19.8 and 21.5 percent respectively of available land resources were utilized in 1975-78.

Table 5 also shows that an average of only 40.8 percent of the total land available to farmers studied was cropped in 1975-78. Percentage land utilization varied however from district to district. The farmers in the Bolgatanga, Tumu and Bawku district utilized the largest percentages of their land resources viz 54.8, 53.8 and 47 percent respectively. Farmers in Sandama, Wa and Navrongo utilized the smallest proportions of their land resources. They utilized an average of 19.8, 21.5 and 29.8 percent respectively of the total available in 1975-78. It must be pointed out, however, that the fact that only around 40% of available land was cultivated per season does not indicate that the 'quantity' of land resource available to the farmers does not impose an immediate constraint to increased production. This is because under the existing system of land rotation, where the only means of regenerating soil fertility is to allow for bush fallow, it is imperative that at any season a substantial portion of available land is allowed to lie idle, or fallow.

Generally in the Upper Region multiple cropping is precluded by the single rainfall regime and the general lack of irrigation water. Consequently, the intensity of land use as measured by The Multiple Cropping Index [1] indicates a low intensity of use with respect to both cropped land and available agricultural land.

Appendix Table 5 gives percentage distribution of the farmers studied in terms of the problems encountered with the land resource available to them. The table shows that only 3% of the total sample had land tenure problems. Low soil fertility was by far the commonest complaint of the farmers. Other than in Lawra 67 percent or more of the total sample had this problem while in the Tumu district the figure was 95 percent. Long distances of farm location was also a concern for 10 percent of the farmers in the Lawra and Wa districts and 8 percent in the Bawku districts.[1]

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[1] $\text{Multiple Cropping Index} = \dfrac{\text{Effective Crop Area}}{\text{Crop Land Area}}$; where Effective Crop Area is obtained by the summation of all acres planted to crops in the successive periods in the given year. Multiple Cropping Index less than unity indicates that the farmer uses his crop land less than once in a year and therefore and denotes low intensity of land utilization.

Labour Resource

Apart from land, labour can impose a serious constraint to production expansion in traditional agriculture. The contemporary view of development economists is that diguised unemployment abounds in traditional agriculture - i.e., the marginal physical product of the additional worker may be very low or even zero and that labour services are easily obtainable for wages above the subsistence wage.[2] However, because agricultural activities exhibit great periodicity, labour shortages may occur and constitute a serious constraint to increased agricultural production under existing farm organization and methods of operation.

Family labour constitutes the principal component of the farm labour force in the Upper Region. Table 6 gives the average family size by district as well as the potential man-days of family labour available per month per farm family.[1] Family sizes were largest in the Lawra and Bawku districts where they averaged 10.8 and 9.2 persons respectively and smallest in the Navrongo and Tumu districts. Correspondingly, the farmers in the Lawra and Bawku districts were estimated to possess the largest potential family labour forces with 131 and 101 man-days per month per farm family. Their counterparts in the Navrongo and Tumu areas possess 62 and 80 man-days of potential monthly family labour supply (see Table 6).

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[1] These are districts where high population pressure continues to push unoccupied land farther and farther away from the settlements.

[2] This is to be distinguished from zero marginal physical product of labour in terms of hours per worker. - See A. K. Sen Choice of Techniques (Oxford Blackwell), 1960.

Family labour is usually supplemented with hired and/or exchange labour. Hired labour used for land preparation and weeding is usually paid in cash while that used for harvesting usually receive payment in-kind as a proportion of the total harvest. Exchange labour is paid with return labour services by the recipient farmer. Labour utilization by the specific enterprises is discussed later in Chapter VI.

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[1] Caution must be taken in the use of the data presented in Table 6. The potential family labour force per month per farm family has been arrived on the following assumptions; i) 5-day working week (there are two market days a week in the major towns); ii) that two females adult - labour units are equivalent to one male-adult unit and two child-labour units (those 10 - 14 years) are equivalent to one adult labour unit; iii) a family is made up of the following ratios of persons 0.92: 0.75: 0.13: 0.66, adult males (15 - 64 years old); adult females; youth aged 10 - 14 years; and the aged (over 64 years) plus children below 10 years, respectively. The ratios were derived from the regional population statistics. See Census Office, op. cit., pp. XLI and XLII.

TABLE 6*

AVERAGE FAMILY SIZE AND MAN-DAYS OF FAMILY LABOUR POTENTIALLY AVAILABLE PER MONTH PER FARM FAMILY

	AVERAGE FAMILY SIZE	POTENTIAL MONTHLY FAMILY LABOUR MAN-DAY
WA	8.0	86
LAWRA	10.8	131
TUMU	7.5	80
SANDAMA	7.7	84
NAVRONGO	5.9	62
BOLGATANGA	7.8	84
BAWKU	9.2	101
AV. REGION	8.5	93

*SOURCE: Derived from Survey Data and 1970 Population Census Statistics.

Capital Resources

Many economists believe that capital accumulation plays a key role in the process of economic development. Kindleberger quotes many economists who hold his view. But he also quotes many others who question the importance of the capital resources in the development process.[1] While capital may not be the primary determinant of economic development, its role in raising labour productivity cannot be ignored. Gadsby has observed that differences in capital resources, more than anything else, distinguishes the agriculture of developing countries from that of the advanced countries.[2]

It is generally believed that agriculture in traditional societies is characterised by an almost absence of capital formation and by a meagre use of capital inputs. While the relative use of capital inputs is low, the hoe and the machet being the major capital equipments used, the notion of an almost complete absence of capital formation may be very simplistic in many cases and may underestimate the values of capital stock that exist in traditional agriculture. Such is the case for cocoa farming in southern and central Ghana and livestock farming in the Northern and Upper Regions of Ghana. In these areas the value of capital stock per farmer is, in fact, high by many standards. In these enterprises the stock of capital takes the form of cocoa trees, the stock animals and seed reserves for the next planting seasons. To these, may be added the often relatively small values of farm equipment, investments in soil improvement measures and the costs of land clearing.

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[1] Kindleberger, Charles P.. Economic Development. New York: McGraw Hill, 1958, p. 83.

[2] Gadsby, Dwright. "Changes in Agriculture in Twenty-Six Developing Nations 1948 - 1963". Foreign Agricultural Economic Report No. 27. United States Department of Agriculture, November, 1965.

In terms of the above, it may be stated that the values of the capital stock possessed by farmers in the Upper Region are higher than traditional agriculture is commonly given credit for. Table 7 presents a breakdown of the capital equipment possessed by the farmers studied in the sample while Table 8 gives the distribution of these farmers by the mean values (at undepreciated replacement costs) of this equipment. The values of bullocks are included where applicable.

The hoe and the sickle/machet are still the basic farming implements. None of the farmers in the sample owned tractors and ownership of bullocks and ploughs was common only in the Bawku districts where they averaged 0.8 and 0.4 per farmer respectively. In the Sandama district, the ratio of bullock and bullock ploughs to farmer was 0.2 and 1. The lowest value of farming equipment was recorded in the Navrongo district where the average value per holder was ¢38.00. The highest average values were found in Bawku and Sandama districts at ¢561.00 and ¢507.00 per holder respectively. These relatively high values in both districts are explained by ownership of bullock

Table 7*

Average Number of Farm Implements and Bullocks Per Holder

Districts	West			East			
Equipments	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku
Tractor	-	-	-	-	-	-	-
Bullocks	-	-	-	0.2	0.2	0.1	0.8
Plough	-	-	-	0.2	0.2	-	0.4
Hoes	2.6	4.3	3.0	3.1	4.9	7.1	5.6
Matchets	3.5	2.3	3.8	1.9	1.7	1.0	1.4
Baskets	2.0	5.9	2.8	1.9	3.5	4.7	3.8
Sacks	4.4	4.8	1.3	0.7	4.1	4.4	4.1
Axes	1.5	0.6	1.1	0.9	-	-	0.4

* SOURCE: Compiled from Survey Data.

Table 8

DISTRIBUTION OF HOLDERS BY VALUE OF FIXED CAPITAL EQUIPMENTS

DISTRICTS	WA		LAWRA		TUMU		SANDAMA		NAVRONGO		BOLGANTANGA		BAWKU		TOTAL REGION		CUMULATIVE
VALUE ¢	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	%
OVER 450	2	(5)	6	(12)	1	(5)	4	(25)	3	(7)	4	(6)	30	(33)	50	(16)	16
401 - 450	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
351 - 400	-	-	2	(4)	-	-	-	-	-	-	1	(1)	1	(1)	4	(1)	17
301 - 350	1	(3)	1	(2)	-	-	-	-	-	-	1	(1)	-	-	3	(1)	18
251 - 300	1	(3)	2	(4)	1	(5)	-	-	-	-	2	(3)	1	(1)	7	(2)	20
201 - 250	3	(8)	6	(12)	4	(20)	-	-	-	-	2	(3)	2	(2)	17	(5)	25
151 - 200	6	(15)	7	(15)	3	(15)	-	-	-	-	2	(3)	2	(2)	20	(6)	31
101 - 150	9	(23)	10	(21)	8	(40)	3	(19)	2	(5)	13	(19)	3	(3)	48	(15)	46
51 - 100	11	(28)	7	(15)	2	(10)	3	(19)	4	(10)	23	(33)	17	(20)	67	(21)	67
0 - 50	6	(15)	7	(15)	1	(5)	6	(37)	31	(37)	22	(31)	34	(38)	107	(33)	100
TOTAL	39	(100)	48	(100)	20	(100)	16	(100)	40	(100)	70	(100)	90	(100)	323	(100)	-

*SOURCE: COMPILED FROM SURVEY DATA.

[1] Total number of holders from whom satisfactory results were obtained.

and ploughs by many farmers in the districts.[1] The average values of capital equipment used by the farmers in the Lawra, Tumu and Bolgatanga were estimated at ¢153, ¢149, and ¢156 per holder respectively. Thus the investment in capital equipment is small. This could constrain efforts to increase agricultural production requiring new forms of capital equipment to take advantage of technological improvements.

The equipment used does not, however, constitute the only fixed capital stock the farmers have in agriculture. A substantial proportions of farmers[2] fixed capital stock is livestock. Appendix Table 6 gives the mean herd sizes of livestock and poultry per farmer by district. The table also gives the average total value of these animals per farmer as well as the average values of those that were sold or used by the households per year. By and large, the number of cattle per farmer was found to be relatively small, averaging from 1.8 in the Navrongo district to 5 in the Lawra district. The total sample average was 3 cattle per farmer. While sheep and poultry were important throughout the region, they were found to be most popular with the farmers in the Sandama district where the average per farmer were 7 and 37.6 respectively. Pigs were relatively unimportant throughout the region.

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[1] Excludes livestock except bullocks used for land preparation and draft purposes. While it may be argued that agriculture in the two districts are more progressive than it is elsewhere in the region. It may be of interest to ascertain whether per capita output and farm incomes are equally higher than elsewhere.

[2] Caution must be exercised in the use of these data since the valuation was based on famer's reservation prices/valuation of the animals which may not necessarily coincide with the going market prices/ valuation. Furthermore, the herd sizes per farmer in the Bolgatanga and Bawku districts appear to be unusually small considering that the two districts are known to hold the largest population of cattle per unit area in the country. The apparent anomaly may be explained by either of the following: i) under - counting during the survey or ii) that ownership of large herds of cattle is restricted to large scale holders who were deliberately excluded from the sample. The latter seems more plausible.

The total value of livestock and poultry per farm family was quite high (see Appendix Tables 6 & 7). It ranged from ¢1953 in the Bawku district to ¢5465 in the Sandama district. The average for the sample was ¢2687. Appendix Table 7 provides the distribution of farm families by the total value of the livestock and poultry they possessed. The table indicates that except in the Bawku and Navrongo districts over 20% of the farm families in all the districts had livestock and poultry valued ¢5000 and above. In the Sandama district the figure was 32%. On the other hand, one-third of the total sample had stock of animals valued at not more than ¢500. In the Bawku district the percentage of such families was 58 while it was as low as 11% and 21% respectively in the Lawra and Sandama districts. From the average values of livestock kept (see Appendix Table 6) and the fixed capital equipment possessed (Table 8), it is estimated that the average farm family had a total of ¢2995 in fixed capital stock committed in agriculture. This figure excludes the value of the investments in land improvement projects, crop seeds and storage facilities which in total are very small.

As discussed in Chapter II, many farmers keep livestock partly as a store of wealth and as a status symbol. In the case of such farmers sales of stock are made only under serious economic exigencies Appendix Table 6 also gives the average values of livestock and poultry sold and/or used by the household per year.[1] Figures in the table indicate that farmers in the Bolgatanga district sold/used the highest value of animals per year. The average for the district was ¢997 per annum. Farmers in the neighbouring Navrongo sold or consumed the lowest value of their livestock and poultry. The average for that district was ¢220 per farm family per annum. The total sample average for the region was ¢668 per farm family per annum (see Table 6).

Sources of Finance

The difficulty of securing adequate working capital was a major complaint of many farmers. Working capital is often needed to hire labour to supplement family labour, to purchase seeds when reserves are exhausted and to pay for other capital inputs. Majority of the farmers financed their operations from their own resources. Only 16 (4.6 percent) out of the total sample of 350 farmers obtained additional financing from outside sources. Of these, 12 (3.4 percent of total sample) received loans from private sources while only 4 (1.1 percent) had access to institutional credit (Banks). This seems to give credence to the assertion that the role of institutional credit in traditional agriculture is still negligible in Ghana. It underscores the need for a more active role by the Banks to provide credit to farmers for the purchase of the inputs needed to increase production and incomes and to modernize the agricultural sector. Production credit can be an important accelerator of agricultural development. Working capital as a constraint to increased production and incomes in the region is discussed later in this study.

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[1] It was not possible to extract accurate information on livestock sales to determine actual cash receipts from this enterprise.

Cropping Patterns

Crops Cultivated and Their Relative Importance to Farmers

Several factors determine the crops cultivated in a given locality. These include the physical conditions of soil and climate which in agriculture are exogenous variables least controllable by farmers. Others are social or cultural factors such as the peoples' eating habits and the level of market demand. Within the dictates of these factors, the final choice of crop/s by the farmer depends upon his subjective evaluation of the relative return (monetary, level of personal satisfaction, etc.) to him of those crops. An understanding of the basis of such evaluation is very important to any viable strategy by government to promote increased production of the crops the farmer produces.

A total of 9 food crops were cultivated by the sample of farmers studied. To obtain the relative importance (evaluation) of these crops farmers were asked to rank the crops in order of their importance to them. Scores of 9 to 1 were then awarded to the crops in a descending

Table 9*

Relative Importance of Food Crops to Farmers by District

	WA		LAWRA		TUMU		SANDAMA		NAVRONGO		BOLGATANGA		BAWKU		TOTAL REGION	
Crops	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Millet	180	6th	305	2nd	171	1st	153	1st	398	1st	360	3rd	719	1st	2286	1st
Sorghum	382	1st	347	1st	152	2nd	72	4th	377	2nd	466	1st	451	3rd	2247	2nd
Groundnut	181	5th	201	3rd	113	4th	118	2nd	317	3rd	308	4th	180	4th	1418	4th
Cowpea	276	2nd	195	4th	131	3rd	109	3rd	255	4th	372	2nd	581	2nd	1889	3rd
Rice	30	8th	77	6th	7	6th	41	5th	64	6th	40	6th	115	5th	374	6th
Maize	186	4th	149	5th	6	7th	-	-	-	-	-	-	-	-	341	7th
Yam	220	3rd	50	8th	-	-	-	-	5	7th	-	-	-	-	275	8th
Bambara Beans	73	7th	72	7th	80	5th	35	6th	229	5th	191	5th	17	6th	697	5th
Sweet Potatoes	-	-	15	9th	-	-	-	-	-	-	-	-	-	-	15	9th

*SOURCE: Compiled from Survey Data.

order of importance as they appeared in the growers ranking. Table 9 gives the results of the scoring.

The table shows that across the region farmers considered millet and sorghum their most important crops - millet being slightly more important than sorghum. Cowpea is the third most important crop followed by groundnut, bambara beans and rice in that order. However, some variations occur in the relative importance of these crops between districts. For example, in the two western districts of Wa and Lawra, sorghum was more important than millet whereas in all other districts except Bolgatanga the reverse was true. Cowpea ranked second in importance after millet in Bawku and after sorghum in Bolgatanga and Wa districts. It placed fourth after millet, sorghum and groundnut in Navrongo and Lawra districts but ranks third in importance in the remaining districts. Groundnut, a major cash crop, occupied fourth position while Bambara beans took the fifth place. Sweet potatoe was the least important crop (see Table 9).

Crop Holdings

Most farmers worked more than one farm. The average number of farms per farmer in the sample was 2.4. Generally, the farmers in the western sector of the region operated more farms per farmer than their counterparts in the eastern sector. The average number of farms per farmer in the Wa and Lawra districts was 3.0 and 3.2 respectively while in the Bolgatanga and Bawku districts they were 1.7 and 2.1 per farmer respectively (see Table 10). Farm sizes were

Table 10*

Average Size of Holding, Farm Sizes, and Returns Per Acre, Per Holder and Per Capita

	Average Size of Holding	Number of Farms Per Holder	Average Farm Size	Average Gross Returns Per Acre ¢	Average Gross Returns Per Holder ¢	Average Gross Returns Per Capita ¢
Wa	9.3	3.0	3.1	192.00	1825.48	228.19
Lawra	12.9	3.2	3.7	300.47	3159.41	292.53
Tumu	18.9	2.0	10.4	160.26	2713.60	361.82
Sandama	3.5	1.5	2.2	175.87	497.09	64.58
Navrongo	3.5	2.2	1.7	305.60	1008.95	171.00
Bolgatanga	2.7	1.7	1.6	256.28	753.10	96.55
Bawku	5.2	2.1	2.5	247.17	1286.48	139.83
Total Region	8.7	2.4	3.6	260.36	1772.75	208.56

*SOURCE: Compiled from Survey Data.

generally, small throughout the region but they were smallest in the Bolgatanga, Navrongo and Sandama where average sizes were 1.6, 1.7 and 2.2 acres respectively. The largest farms occurred in the Tumu district where the average was 10.4 acres. Average farm size for the total sample was 3.6 acres for the whole region (see Table 10). The fragmentary characteristic of holdings has resulted partially from the system of inheritance in the region and does constitute a barrier to efficient farm mechanization. In addition, farms under one holding are usually separated by considerable distances and this causes considerable loss of time and energy from commuting among them. One merit of the situation however, is that it enables farmers to have land of differing quality and suitability for their respective crops.

The system of intercropping practised alongside pure cropping, allows for a large multiplicity of crop enterprises.[1] Assuming independence or crop compartibility, a total of 256 different crop enterprises are possible. These comprise 247 intercrop and 9 pure-crop enterprises. However, few of these possible combinations occurred within the sampled holdings studied.

Table 11 gives the most popular combinations encountered in the various districts. These were the enterprises that occurred most frequently on the holdings studied and occupied the largest proportions of the acreage cultivated. The table indicates that in the Wa district, for example, a mixture (intercrop) of sorghum, maize and cowpea or a mixture of sorghum, late millet and cowpea or sorghum and maize usually occur on the farmers' first farms (these are the farms nearest to the settlements - called here the 'compound farms'). Yams as pure crop are cultivated on the second farms. Other crops/enterprises found on farmers' third farms (the remotest from the settlements) are rice, maize and groundnut each as pure crop enterprise. It is in the region for the most distant farms to be devoted to cash crops.

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[1] Enterprise here denotes the crop or cropmix on a given farm (field), the latter being the productive unit.

Crop budgets for the most popular enterprises are given in Appendix Table 8:1- 8:11. The budgets provide information on labour expenditure on various operations, and returns per acre and per man-days of labour. The budgets indicate that the intercrop enterprises, generally, yield higher returns per acre than the pure-crop enterprises. The returns, however, vary among the enterprises and also among the districts. Returns per man-day of labour are generally higher in the Bolgatanga and Bawku districts than elsewhere in the region. This is explained by the more wide-spread use of animal and tractor power by farmers in the two districts.

Relative to other pure-crop enterprises cowpea gives the lowest gross returns and gross margins per acre in all the districts. The average regional gross margin per acre of pure-crop cowpea is ¢83.00. This compared with ¢209.90, ¢176.30 and ¢253.35 for millet, sorghum and groundnut respectively. Correspondingly, pure-crop cowpea also

Table 11*

The Most Popular Crop Enterprises and the Farms They Occur[1]

	FARM I	FARM II	FARM III	FARM IV
Wa	S-Ma-Cow S-Lm-Cow S-Ma	Yam Gn-Bam Gn-Cow	Yam Rice Ma Gn	--
Lawra	S-Ma-Cow S-Cow	Lm Gn-Bam	Yam Ma	Gn Cow
Tumu	Lm-S-Cow	Gn-Bam Gn		
Sandama	Em-Lm-S-Cow	Em-S-Cow Rice Gn-Bam		
Navrongo	Em-Lm-S-Cow	Gn-Bam Lm-Cow-Gn	Gn Rice	
Bolgatanga	Em-Lm-S-Cow Em-S-Cow S-Em	Em-Lm-Cow Gn-Bam Gn Rice		
Bawku	Em-Lm-S-Cow Lm-Cow Lm-S-Cow	Gn Em-S-Cow	Rice	

*Compiled from Survey Data.

KEY: S = sorghum EM = Early millet Lm = Late millet Ma = Maize Cow = Cowpea
Gn = Groundnut Bam = Bambara beans

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[1] Farms (fields) are numbered I - IV according to their distance from the homestead.

gives the lowest returns per man-day of labour, average ¢3.22 for the region (see Appendix Table 8:1- 8:4). This low competitive position of pure-crop cowpea is explained primary by low yields. The average regional yield is only 290 lbs per acre (see Appendix Table 8:3).

Returns from Crop Production

Physical yields and relative prices are the two major determinants of gross returns (output) per acre of a crop enterprise. Yields varied widely from farm to farm and among districts and so did the value per unit of each crop. Table 10 gives the average gross returns per holder by district, the average incomes per farm family from crop production as well as the per capita gross incomes from the same source.

The Table 10 indicates that gross returns per acre were highest in the Bolgatanga and Lawra districts. They averaged ¢305.60 and ¢300.47 per acre respectively but were lowest in the Tumu district, average ¢160.26 per acre. The sample average was ¢260.36 of gross returns per acre for the region. It is perhaps significant that gross returns were lowest in the Tumu district where the average size of holdings per farmer and farm sizes were the largest in the region. It is perhaps equally important to note that average gross output (returns) was highest in the Navrongo district where the average farm size and the size of holding per farmer averaged only 3.5 acres. From a survey work in the Bawku district, LARC discovered a negative correlation between income per acre and total farm acreage.[1] This appears to be applicable here where farmers in the relatively land scarcity districts of Bolgatanga, Navrongo, Lawra and Bawku compensate for smaller land resource through the choice of high value crops and good management practices (e.g., greater care over land preparation more timely planting and weeding) to achieve higher returns per acre than elsewhere.

Table 11 also gives per capita gross output in value terms from crop production. The average per capita returns for the region from crop production was estimated to be ¢208.56 for 1978. This was equivalent to a total gross returns of ¢1772.75 per farm family. The table indicates that on a per capita basis farmers in the western sector of the region (Wa, Lawra and Tumu districts) were richer crop farmers than their counterparts in the eastern sector. The relatively poorest crop farmers were in the Sandama and Bolgatanga districts where per capita gross returns averaged ¢64.58 and ¢96.55 respectively (see Table 10).

Concluding Remarks

Farmers in the eastern sector of the region are more prosperous livestock producers than their counterparts in the west. However these positions are reversed in crop production. The highest value of livestock occur in the Sandama and Bolgatanga districts. Potential for increased crop production is higher in western sector. Crop production is labour intensive throughout the region and is characterized by a virtual absence of improved technology.

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[1] LARC found correlation coefficients of minus 0.87 and minus 0.42 between income per acre and total farm acreage per farmer for Pusiga and Binduri respectively, two villages in the Bawku districts. See Land Use Agricultural Production, Land Tenure and Administration, by LARC, op. cit., p. 42.

Farmers generally consider cowpea as their third most important crop after millet and sorghum. Cowpea is cultivated primarily for food, for livestock use and for its benefits to other crops in the rotation, however, surpluses occur to generate some cash incomes. The relative profitability of cowpea cultivation is low compared to other crops. Attempts to improve its output would therefore require a substantial rise in its profitability to make it competitive. Such attempts may consider the following: i) the use of improved seeds, fertilizers and pesticides to raise yields, ii) input and output pricing policies in favour of cowpea.

CHAPTER V

SUPPLY RESPONSE FOR COWPEA IN THE UPPER REGION

The models of the 'inert' or 'satisficing peasant' bound by custom and tradition, unresponsive to new production and consumption possibilities and putting forth only the effort required to attain a fixed income target have been countered by those presented by Schultz, Hopper and by Hayami and Ruttan.[1] Schultz's construct is that of the 'optimizing peasant', a shrewd fellow who has learnt through experience to allocate his resources efficiently and 'is responsive to economic incentives within his perceived opportunity set'.[2] This view is supported by the weight of available empirical evidence, for example, Krishna has observed that even subsistence crops respond to relative prices.[3] Nonetheless, efficiency differences do occur and exist among farms and across regions even within any given country. These apparent deviations from optimizing behaviour can not be explained simply by peculiarities of motivation but rather by the nature and variety of constraints on economic behaviour. Prominent among these constraints are the uncertainities inherent in agricultural production and the aversion to risk which is particularly associated with low income farm families and families with small cash reserves. The peculiarities of land as an asset and the imperfections in rural capital markets also militate against optimizing behaviour by farmers. Reynolds argues that all these factors retard and even prevent movement towards 'a hypothetical equilibrium or cause adjustment to stop at peculiar values (other than optimal values) of one or more variables'.[1]

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[1] See David Hopper Allocative Efficiency in a Traditonal Indian Agriculture. Journal of Farm Economics, Vol. 47, August, 1965, pp. 611 - 24 and Ruttan, V.W.and Hayami, Y. Agricultural Development: An International Perspective. Baltimore: John Hopkins Press, 1971 and T.W. Schultz. Transforming Traditional Agriculture. New Haven: Yale University Press, 1964.

[2] ibid.

[3] Raj Krishna "Agricultural Prices Policy and Economic Development" in Southworth and Johnston (Eds), op. cit.

Consistent with allocative efficiency, peasant producers are now known to respond to changes in the direction predicted by economic reasoning. More precisely, they respond positively to changes in relative input and output prices although the magnitude of response varies with their circumstances. The importance of a knowledge of the direction and magnitude of such responses for policy purposes can hardly be over-emphasised. It helps to predict beforehand the effectiveness of selected policy instruments to achieve production targets. A knowledge of the supply response is necessary to select the appropriate policy instruments and the extent to which they are applied.

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[1] See Lloyd G. Reynolds. "Agriculture in Development Theory: An Overview" in Agriculture in Development Theory. New Haven and London: Yale University Press, 1975, p. 6.

This chapter pursues such information. Initially the economics of cowpea production vis-a-vis other crop enterprises is briefly outlined. A supply function is then formulated based on the Nerlovian Adjustment Lag Model and estimated firstly by the Ordinary Least Square method and secondly by the Instrumental Variable method. The chapter concludes with the discussion of the results obtained from these estimations.

Cowpea's Place in Farmers' Programmes

Cowpea (Vigna unguiculata) is a legume with high (23%) digestible protein content.[1] The bean is widely consumed throughout Ghana (and West Africa as a whole) but in the Upper and Northern Regions of Ghana the leaves are consumed as well. Per capita consumption of the bean was estimated at 13 - 15 kg per annum in 1975[2] and a large potential demand exists. Because of its high protein content, cowpea is widely considered an inexpensive supplement to fish, livestock and game which constitute the largest traditional protein supply sources for Ghanaians. As a field crop, cowpea possesses several advantages. It has a relatively short maturing period of 3 - 4 months depending on the variety. This means that one to three crops may be obtained during the year depending upon availability of good moisture conditions. Like most legumes, cowpea has soil enriching capabilities which makes its occurrence in crop rotations beneficial to subsequent crops.

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[1] See Arkoyd, W.R. and Doughty, J. Legumes in Human Nutrition. FAO Nutrition Studies, No. 19, Rome, 1964.

[2] Kuranchie, P.A. op. cit.

In spite of the professed importance of cowpea to the farmers (see Table 9) and of the fact that it features prominently in the diets of the people in the region, it is cultivated principally as a subsidiary crop and rarely in pure stands. The total acreage devoted to the crop in the region is relatively small. Table 12 gives the proportion of farmers' crop holdings devoted to cowpea in 1978.

Table 12*

Average Acreage of Cowpea Per Holder by District 1978

District	% of Holders with Cowpea	Ave. Size Holding/ Farmer (Acres)	Ave. Area of Cowpea per Holder (Acres)	% Cowpea of Holding
Wa	84	9.3	.5	5.4
Lawra	74	12.9	.8	6.2
Tumu	100	18.9	1.0	5.3
Sandama	100	3.5	.5	14.2
Navrongo	100	3.5	.3	8.6
Bolgatanga	99	2.7	.4	14.8
Bawku	100	5.2	.5	9.6
Total Sample	95	8.7	.5	6.0

*Source: Compiled from survey data.

The table indicates that in the Sandama and Bolgatanga districts where farmers allocated the largest proportions of their holdings to the crop, cowpea occupied an average of only 14.2 and 14.8 percent (0.5 and 0.4 acre) of holdings respectively. In the other districts, the proportions of the total holdings devoted to the crop were very much lower. Out of the total sample of farmers studied, however, 95 percent grew cowpea and the area planted to it in 1978 averaged 6 percent of holdings, 0.5 acre per farmer that year.

Several factors may explain the rather small portion of land resource allocated to the crop inspite of the relatively high premium farmers seem to place on it. Among these, farmers indicated that cowpea is a high risk crop which requires proper timing of seeding in order to obtain satisfactory pod formation. This risk is exacerbated by the crop's high susceptibility to weevil infestation which accounts for up to 20 percent reduction in yields. These factors together with the poor genetic quality of available varieties are responsible for the low per acre yields obtained by farmers in the region. Average yield in the region was estimated at only 290 lb. per acre (see Appendix Table 8:3). This contrasts with yields of up to 1900 lb. per acre which have been obtained with some imported varieties.[1] Another peculiar difficulty with cowpea as cited by the farmers, had to do with storage. The damage resulting from weevil infestation in the field continues during storage because farmers lack adequate means to prevent losses from this cause. To prevent excessive post-harvest losses, farmers sell off their surpluses during the harvest season. Farmers are therefore unable to speculate on future prices and are unable to obtain prices remunerative enough to serve as incentives for increased production. Thus the subsidiary status of cowpea is dictated by economic rather than cultural or social considerations. It is relatively a less profitable crop. Indeed, cowpea was found to be the least profitable pure-crop enterprise in the region. Average net return per man-day of labour was estimated at ¢3.32 (lower than the statutory wage of ¢4.00, see Appendix Table 8:3). This contrasts with the second least profitable crop (maize in Wa and Lawra districts) with a net return of ¢3.85 per man-day (Appendix Table 8:6 and compares with groundnut which returned an average of ¢7.60 per man-day of labour (Appendix Table 8:4). It is understandable therefore that farmers behaving rationally are more inclined to make more investment in groundnut than in cowpea production.

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[1] See World Bank. Appraisal of Upper Region Agricultural Development Project, op. cit. Annex 2, p. 12.

The Supply Model

Several models have been used to study supply response in agricultural production.[1] The present study specifies an acreage response of (a single crop) cowpea produced under semi-subsistence conditions. This is to be distinguished from yield response where farmers are postulated to allocate non-land resources in response to output price changes. The use of acreage as proxy for output has two major drawbacks. Firstly, the price elasticity of acreage is considered to be a good minimum approximation of price elasticity of output only if (i) all the other inputs can be varied pari passu, when the acreage of the crop is varied and (ii) there is absence of diminishing returns to scale.[2] Clearly in a near subsistence agricultural economy where land and labour are the chief resource inputs, labour and land can be varied simply by reallocation among alternative crops. Secondly, land is an input in the production process and according to neo-classical production theory, the derived demand for a factor input is a function of expected output, and input prices including lands opportunity cost, rents.[1] Thus the supply response formulated in terms of acreage may indirectly measure the derived demand for land for the particular crop in question - usually without including some important exogenous variables like the prices of all other inputs. This occurs if the function used is not carefully specified.

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[1] For detailed description of alternative models and techniques of supply analysis, see Agricultural Supply Functions -- Estimating Techniques and Interpretation. E.O, Heady, et al. Ames, Iowa: Iowa State University Press, 1961 and Agricultural Supply Response: A Survey of the Economic Evidence. Hossein Askari and J.H. Cummings. New York: Praeger Publishers, 1976.

[2] 'Agricultural Prices Policy and Economic Development' by Raj Krishna in Agricultural Development and Economic Growth. H.M. Southworth and B.F. Johnston (eds). Ithaca, N.Y.: Cornell University Press, 1967, pp. 497 - 547.

Inspite of the above, the use of acreage as proxy for output is intuitively appealling and often methodologically convenient. Especially in traditional agriculture, farmers have more control over the allocation of the quantity of available land resource among enterprises than over total output since the latter is influenced by elements (e.g. vargaries of weather, disease) beyond their control. Because of these factors the realized output response with respect to prices may not fully reflect the behaviour of the farmer. Since the basic object of response studies is the intention of the producer, specification of response model with the quantities of physical output as the endogenous variable may give misleading results.[2] In the above circumstances, then planned acreage provides a better proxy of intended production than the quantities of realized output. Furthermore, acreage data may be more reliable than data on physical output (since in Ghana, for example) the latter is usually estimated from planted acreage. However, since planned acreage is usually an unobservable variable, the response equation in this study is based on the Nerlovian Adjustment Lag model. The model is described below.

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[1] This may be formulated as follows: $qd_{land} = f(Q, P_Q, P_{labour}, Rent)$. See R. Shone. *Microeconomics: A Modern Treatment*. London: MacMillan Press Ltd., 1975.

[2] See J.R. Behrman. 'Price Elasticities of the Marketed Surplus of a Subsistence Crop', *Journal of Farm Economics*, Vol. 48, Part I, 1966, pp. 875 - 893, and also A. Yotopoulos and J.B. Nugent. *Economics of Developing Empirical Investigation*. 1st ed. Hagerstown, N.Y.: Harper and Row Publishers, 1976, pp. 136 - 137.

Given that the desired or planned acreage of cowpea in year 't' (A^*_t) is a function of its own price in the previous year (PC_{t-1}), i.e., $A^*_t = f(PC_{t-1} \ldots.)$ (1) with the Nerlovian adjustment model, the relationship between the actual acreage planned (A_t) and the desired acreage may be specified as follows:

$$A_t - A_{t-1} = \Psi(A^*_t - A_{t-1}) \;\ldots.\; \xi_t \qquad (2); \quad 0<\Psi \leq 1$$

$$= \Psi A^*_t - \Psi A_{t-1}$$

$$A_t = \Psi A^*_t + (1-\Psi)A_{t-1} \cdot \xi_t \qquad (2^1)$$

$$A^*_t = \frac{A_t}{\Psi} + \frac{\Psi-1}{\Psi} A_{t-1} \;\ldots\; \frac{\xi_t}{\Psi} \qquad (3)$$

Equation 2 implies that the actual acreage planted in year 't' (A_t) is a function of the difference between the desired/planned acreage for that year (A^*_t) and the actual acreage planted in the previous year (A_{t-1}). Alternatively, as indicated by Equation 2^1, the actual acreage planted (A_t) is a weighted average of (Ψ and $1-\Psi$) the desired/planned acreage and actual acreage planted the previous year respectively. The model postulates that in response to output price changes, producers adjust their production decisions such that the actual acreage planted approaches their desired/planned acreage.[1] The parameter Ψ is the coefficient of adjustment and the value of $\Psi = 1$ denotes complete adjustment - where actual acreage planted coincides with the desired/ planned acreage ($A^*_t = A_t$).

In addition to enabling the measurement of desired/planned output, the Nerlovian adjustment model is used in this study because of its conceptual appeal and other inherent advantages. For example, it enables the separate estimation of short and long run elasticities,[2] and produces higher R^2 values than alternative models. Furthermore, it yields more efficient estimates of supply elasticities with more reasonable signs and appears to eliminate the problems of serial correlation

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[1] The reasons why a complete adjustment of $A^*_t = A_t$ is not achieved in a single year may include technological constraint, institutional rigidities and persistence of habits. For more precisely formulated rationale within a particular context see Z. Giliches 'Distributed Lags: A Survey'. Econometrica, Vol. 35, January, 1967, p. 43.

[2] Using the model formulated in this study, the short and long run price elasticities of supply are given respectively by:

$$\varepsilon_{SR} = \Psi\alpha_1 \frac{\overline{PC}_{t-1}}{\overline{A}_t} \quad \text{and} \quad \varepsilon_{LR} = \alpha_1 \frac{\overline{PC}_{t-1}}{\overline{A}_t}$$

where PC_{t-1} and A_t are the means of the own price of cowpea and acreage planted (to cowpea) respectively.

in the residuals.[1]

An adequately specified supply function of agricultural commodities should include all factors which affect the production process. A simple relation between the quantity of output and its price obscures the complexity of the supply process.[2] Other important supply shifters include tne technical relationship between input and output and the objectives and other determinants of the behaviour of firms (farm families). Because of the dearth of data on these factors, only a few of these other variables can be considered in the present study. It is postulated in this study that farmers' desired/planned acreage of cowpea is determined by the own price of cowpea, the prices of groundnut and millet in the previous year and by the amount of rainfall experienced before seeding time Viz:

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[1] For detailed of the merits of The Nerlove Adjustment Lag Model see the following: (i) Nerlove Marc. The Dynamic of Supply: Estimation of Farmers Response to Price. John Hopkins Press, Baltimore, U.S.A., 1958. (ii) Nerlove Marc. 'Distributed Lags and Estimation of Long-Run Supply and Demand Estimates: Theoretical Consideration'. Journal of Farm Economics, Vol. 40, No. 2, May, 1958. (iii) Singh, R.D. et al. 'Estimation of Agricultural Acreage Response Relationship: Some Methodological Issues'. Indian Journal of Agricultural Economics, Vol. 29, No. 1, January - March, 1974. (iv) Askari, H. and Cumming, John. Agricultural Supply Response - A Survey of Econometric Evidence. Centre for International Studies, MIT, 1974.

[2] See "The Nature of the Supply Function for Agricultural Products", Johnson, D. Gale. Readings in the Economics of Agriculture. Karl A. Fox and Johnson, Gale D. (Eds). Homewood, Illinois: Irwin Inc., 1969, pp. 247 - 271.

$$A^*_t = f(PC_{t-1} PG_{t-1} PM_{t-1} RN) \qquad (4)$$

Adopting the Nerlovian Adjustment model derived above and postulating a multiplicative supply response function the equation to be estimated becomes:-

$$A_t = K\, PC_{t-1}^{\alpha_1\Psi}\, A_{t-1}^{(1-\Psi)}\, PG_{t-1}^{\Psi\alpha_2}\, PM_{t-1}^{\Psi\alpha_3}\, RN^{\Psi\alpha_4} \qquad (5)$$

which when linearized in logarithms for estimation becomes:

$$\ln A_t = \ln K + \Psi\alpha_1 \ln PC_{t-1} + 1-\Psi \ln A_{t-1} + \Psi\alpha_2 \ln PG_{t-1} + \Psi\alpha_3 \ln PM_{t-1} +$$

$$\Psi\alpha_4 \ln RN + \Psi\, U_t \qquad (6)$$

where:

A_t = actual acreage planted to cowpea in year 't'

A_{t-1} = lagged acreage of cowpea

PC_{t-1} = lagged price of cowpea

PG_{t-1} = lagged price of groundnut

PM_{t-1} = lagged price of millet

RN = total inches of rainfall January to May inclusive

U_t = error term

Ψ = adjustment coefficient

K = is a constant (shift parameter).

Although in Equation 5 or 6 the supply response has been postulated as an exponential or multiplicative relationship, linear and semi-logarithmic formulations were also fitted and tested with the R^2 't' and F statistics to ascertain which formulation had the highest explanatory power.

Assumptions of Model and Hypotheses

Krishna has argued that wherever a minimal development of transport and monetization has occurred, both traditional and commercial farmers behave identically with respect to the degree of their positive responsiveness to economic opportunities.[1] The Upper Region of Ghana is sufficiently open for its farmers (both traditional and commercial) to respond positively to economic opportunities. Farmers elsewhere in Ghana are well-known for such responses.[2] For example, Bateman's estimates of 0.77-1.28[3] for long-run supply elasticity of cocoa (1942 - 61) provide evidence that the peasant farmer in Ghana responds positively to the prospects for higher income. Based on these premises the following hypothesis are made in the study:

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[1] See 'Agricultural Prices Policy and Economic Development' by Raj Krishna in Agricultural Development and Economic Growth. Ed. Southworth and Johnson, op. cit., p. 508.

[2] Cocoa farmers in Southern Ghana are acclaimed to respond as expected to economic incentives - see Polly Hill. The Migrant Cocoa Farmers of Southern Ghana: A Study in Rural Capitalism. London: Cambridge University Press, 1963. Also see Farmers in the Southern Savanna of Ghana by R.E. Bigelow. Ph.D. Thesis, Department of Geography, Michigan State University, 1973, Unpublished.

[3] Bateman, M.J. "Supply Relations for Perennial Crops in Less Developed Areas" in Subsistence Agriculture and Economic Development. Ed. C.R. Wharton, Jr. Aldine Publishing Co., 1969.

(i) that both the short and long run price elasticities of supply of cowpea are positive although the values for both are expected to vary slightly since cowpea is a semi-subsistence crop. Krishna observes that because of the factors constraining peasant behaviour in dual agriculture, subsistence crops respond little to relative price variations while crops grown for both subsistence and sale respond moderately.[1]

(ii) that the cross price elasticities of cowpea with respect to groundnut and millet are negative. This hypothesis presumes that both groundnut and millet are competitive to cowpea. Agronomically, however, cowpea and millet may be complementary since the former fixes nitrogen which benefits the latter. They are, however, competitive for the farmer's productive resources.

(iii) Finally it is hypothesized that the supply (acreage) response with respect to rainfall is negative. This should be consistent with risk aversion. That is, farmers are expected to put more land under cowpea in order to minimize the loss of total output (harvest) due to poor rainfall.

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[1] Raj Krishna categorizes the magnitude of supply elasticities of single crops according to role of the crop in the economy - from subsistence to strictly cash crops - see "Agricultural Prices Policy and Economic Development" in Agricultural Development and Economic Growth. Ed. Southworth and Johnston, op. cit.

Data

The data used for the estimation of the response equation are given in Appendix Table 9. They are time series data on acres of cowpea and groundnut, average yearly wholesale prices of cowpea, groundnut and millet and an average total rainfall from January to May for the period 1963-1977. The acreage and price data were obtained from the annual and monthly reports of the Ministry of Agriculture respectively while the data on rainfall were extracted from the Annual Reports of the Meteorological Department.

The data used are not without weaknesses. For example, the most appropriate price data to use in the present study would be the farm gate prices received by farmers in their villages at harvest time (when most of the cowpea is sold). However, such data was unavailable. Hence average yearly wholesale prices that ruled the major urban markets were used although they may not necessarily be relevant to many rural farmers. The use of such data in response analysis presumes that the marketing system works sufficiently well that variations in urban wholesale prices are accurately transmitted back in the variation in farm gate prices on which farmers base their production decisions. This presumption is most likely to be inaccurate since agricultural marketing in Ghana is widely reputed to be inefficient and a major bottleneck to increased agricultural production.[1]

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[1] For the discussion of inefficiencies in agricultural marketing in Ghana see Nyanteng, V.K. and Van Apeldoorn, G.J. The Farmer and Marketing of Foodcrops. Technical Publication No. 19, Legon: Institute of Statistical Social and Economic Research, 1971.

In addition, to the apparent inappropriateness of the price data, their reliability and that of the acreage data may be suspect. More accurate data on crop acreages in Ghana date since 1970, the year of the first agricultural census. Agricultural data before that year are deemed to be generally less accurate. Another drawback is the shortness of the time series obtained.

Estimation of the Model

Estimation of adjustment lag models may present a number of difficulties. Firstly, with the presence of the lagged dependent variable in the equation, the coefficient of this lagged variable may encompass a number of influences including those associated with trends in the dependent variable e.g., technological change. This is analogous to the problem of omitted variables that are correlated with included variables. They lead to biased coefficients.[1] Secondly, and more important, the lagged dependent variables may lead to situations where the disturbance terms are auto-regressive or serially correlated $E(U_tU_{t-1}) \neq 0$ and correlated with the lagged dependent variables. As well, multicollinearity may exist between the lagged dependent variable and other explanatory variables. Under such circumstances the assumption of the classical linear model are violated and the application of ordinary least square techniques yields estimates without the desired asymptotic properties i.e., implies inconsistent and inefficient estimates.[1]

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[1] See Brandow, G.E. "A Note on the Nerlove Estimates of Supply Elasticity" and reply by M. Nerlove. Journal of Farm Economics, Vol. 40, August, 1958, pp. 719 - 28, and also Griliches, Z. "Specification Bias in Estimates of Production Functions". Journal of Farm Economics, Vol. 39, January, 1957, p. 8 - 20.

Two approaches to the problems of inconsistency and inefficiency in the parameter estimates from the adjustment model are (i) to employ the non-linear maximum likelihood estimating technique and (ii) to employ the instrumental variables technique. This study uses the latter technique because of convenience and its simplicity. The results obtained are compared with those obtained from ordinary least square technique after the data have been adjusted in attempt to alleviate the problems of multicollinearity.

In preparation for estimation, the price data were deflated by the consumer price indices (CPI) for the corresponding years. This was done on the assumption that farmers buy and sell on the open market and are therefore affected by the general level of prices. Since the weight (of cowpea) in the CPI is negligible no bias occurs from such deflation. A Farrar Glauber test[2] revealed a fairly high degree of multicollinearity between the price of groundnut and the remaining explanatory variables which indicated that the price of groundnut could be dropped from the equation without much loss of explanatory power. However, to minimize further any degree of multicollinearity that may exist the prices of groundnut were used to normalize all the variables in the equation for all the corresponding observations.

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[1] For a thorough discussion of the assumptions of the classical linear model and the problems of their violation see Jan Kmeta, Elements Econometrics. New York: The MacMillan Co., 1971, pp. 380 - 405, and M.D. Intriligator, Econometric Models, Techniques and Applications. Englewood Cliffs, New York: Prentice-Hall, 1978, pp. 150 - 203.

[2] For details of the Farrar Glauber test of multicollinearity see Dale, Orr. Applied Econometrics. Institute for Public Analysis, Toronto: University of Toronto, 1977, pp.

The principal prerequisite for the use of the Instrumental Variable technique (IV) is the procurement of variables to be used as instruments which are (i) independent of the Stochastic disturbance term in the equation (to be estimated) i.e., $\text{plim}\ (\xi Z'_i U^*_i)/n = 0$ and (ii) that the instrument variable(s) and the original variable(s) are correlated i.e. $\infty \angle \text{plim}\ (\xi Z'_i X^*_i)/n > 0$. In this study the planted acreage of groundnut is used as the instrument variable for the cowpea acreage. Because the price of groundnut does not appear in the estimated equation for the above reason, the groundnut acreage satisfies the two above conditions.[1] The other explanatory variables remained as instrument variables for themselves.

Results

Ordinary least square estimation of the linear and semi-logarithmic versions of the modified Equation 5 or 6 gave statistically insignificant results in terms the 't' and 'F' statistics indicating those formulations have no explanatory power. Their results are therefore not presented. Table 13 gives the results of the exponential/multiplicative model as modified. For the purposes of comparison, results from both the OLS and IV techniques are presented. The table shows that the IV technique produced better results. It gave more significant coefficients, higher R^2 values and F statistics. In other words, the explanatory power of the model was enchanced using the IV than with the OLS technique. The Durbin-Watson statistic at 5% and 1% indicated the absence of serial correlation in the equations estimated (see Table 13).

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[1] For detailed exposition of the Instrumental Variable Technique see Jan Kmenta, Elements of Econometrics. Op. cit. and M.D. Intriligator, Econometric Models, Techniques and Applications, op. cit.

In general the signs of the estimated coefficients conformed with a priori economic theory. The own-price elasticity of supply (acreage response) was positive in all the estimations. It was 0.4967 in the IV estimation and significant at 0.05 level. From the result of that estimation the short-run and long-run price elasticities of supply were calculated to be 0.078[1] and 2.26[2] respectively which mean that

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[1] $\xi SR = \Psi\alpha_1 \frac{\overline{PC}_{t-1}}{\overline{A}_t} = .4969 \left(\frac{27.08}{171.43}\right) = 0.078$

[2] $\xi LR = \alpha_1 \frac{\overline{PC}_{t-1}}{\overline{A}_t}$, since $1-\Psi = .9651$ Ψ = the adjustment coefficient $= 0.0346$. since $\Psi\alpha_1 = .4967$, $\alpha_1 = \frac{.4967}{.0346}$

$$\therefore \xi LR = \frac{.4967}{.0346}\left(\frac{27.08}{171.43}\right) = 2.26$$

OR $\xi LR = \xi SR/\Psi$ $\therefore$ in the long run $\Psi = 1$ & $A^*_t = A_t$

Table 13

Results of Estimated Cowpea Supply (Acreage) Response Estimated Coefficients[a]

	Intercept	PC_{t-1}	A_{t-1}	PM_{t-1}	RN	R^2	F	DW^b
A. OLS Technique	3.2026	.8119 (.7636)	.4435* (.2703)	-.2451 (.7232)	-1.4940** (.7235)	.5549	2.8054	2.1699++
	3.1296	.5767** (.3041)	.4458* (.2580)	———	-1.4529** (.6810)	.5493	4.0618T	2.1134++
B. Instrumental Variable Technique	1.9418	.7251 (.7571)	.9610** (.5321)	-.2374 (.7064)	-1.6266** (.6675)	.5754	3.0493	2.3239++
	1.8600	.4967** (.3033)	.9654** (.4841)	———	-1.5872*** (.5981)	.5701	7.2932TT	2.2579++

a Standard Errors are in parentheses

b Durbin Watson Statititic

*** Coefficient significant at 0.025 level

** Coefficient significant at 0.05 level

* Coefficient significant at 0.10 level

++ Hypothesis of no Serial Correlation accepted

T F-Distribution at 5% significant

TT F-Distribution at 1% significiant

short run price elasticity of cowpea supply is very low. This was to be expected since cowpea is a subsidiary crop enjoying a near subsistence status in the study area and provides supplementary benefits to other crops.[1] Also, as expected, the long run elasticity is larger. It indicates that in the long run a one percentage change in the price of cowpea will lead to 2.25 percentage change in the acreage planted to cowpea. Thus Hypotheis One of the study, namely, that the acreage planted to cowpea is directly correlated to the price of cowpea in the previous season is accepted. This has a long term policy implication.

The results also show that past acreage of cowpea has a large positive and significant influence on present acreage. Last year's acreage explains substantially the current year's acreage planted to the crop. This seems to have something to with tradition, the subsistence nature of the crop and the fact that farmers adhere to planned rotation. It is consistent with the reasons the majority of the farmers assigned for cultivating the crop - namely, because their fathers and forefathers cultivated it; it benefits other crops; that it is a major food item and contributes cash income. Clearly the latter aspect is not the most important consideration.

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[1] Raj Krishna classifies short-run acreage elasticities into the following .0 - 0.1 (as low response); 0.1 - 0.4 (as medium response) and 0.4 - 0.7 (as high respond) and observes that most crops falling into first category in a dual agriculture are subsistence crops. From the results, cowpea falls into that category. See Raj Krishna "Agricultural Price Policy and Economic Development" in Southworth and Johnston, op. cit.

The cross price elasticity of supply of cowpea (acreage) with respect to millet was negative indicating cowpea is competitive to millet. This result was not unexpected except that it was statistically insignificant. The result suggests multicollinearity between the prices of cowpea and millet.

Perhaps the most interesting result was the nature of the influence of the amount of rainfall experienced up to and including seeding time. The cowpea (acreage) response with respect to this variable is negative large (-1.5872) and significant at 0.025 level. Thus Hypothesis Three of the study, namely, that farmers adjust their cowpea acreage according to rainfall variability, is accepted. The result suggests that with high rainfall (up to planting time) farmers reduce the acreage planted to cowpea supposedly in favour of the more favoured crops - possibly millet, sorghum and groundnuts. It is also possible that farmers consider heavy rainfall at that time less favourable for good cowpea yields. The entire phenomenon appears to require agronomic explanation. It is apparent from the results, however, that heavy rainfall alone may not encourage increased cowpea production - it will reduce it! Finally the variables in the model explain only 57 percent of the variations in cowpea acreage. This indicates that there are important variables outside the model which constrain increased cowpea production in the region studies.

Concluding Remarks

The results confirm the superiority of the instrumental variable technique over the ordinary least square technique for estimating supply response based on adjustment lag. Cowpea farmers are responsive to changes in the price of cowpea but the short run responsiveness is consistent with the near subsistence status of the crop. The response analysis indicates that there are other important factors besides cowpea price, rainfall and the previous year's acreage which influence farmers' decisions to produce cowpea. These factors may include cultural, social and institutional factors. Thus farmers need more than price incentives to produce more cowpea. One important conclusion is that the amount of moisture available at planting time has considerable influence on farmers cropping decisions. One important drawback of the analysis has been the limitations in the data. Intra-regional variations in prices were concealed by the regional figures. Furthermore the accuracy of the data used may be suspect.

CHAPTER VI

OPTIMUM PROFIT MAXIMIZATION PLANS AND NORMATIVE SUPPLY RESPONSE OF COWPEA

The economic growth and well being of the agricultural industry depends upon the optimality of resource allocation between the industry and the other sectors of the economy and the optimality of resource allocation within the industry itself. Neo-classical production theory indicates that resources are optimally allocated in production when, under existing factor and output prices and the state of technology, resources in alternative employments receive the same returns, i.e., marginal returns equivalent to their marginal value product and reallocation is not possible without loss of productivity.[1] While optimal resource allocation prevails in traditional agriculture, deviations from optimality may occur due to some of the factors discussed in earlier chapters IV and V. In such situations, policy actions may be needed to effect rapid change. For maximum effects, however, such policy actions are best predicted on a thorough knowledge of existing situation at the farm level-including current allocation patterns and constraints (technological, institutional and resource constraints) facing the farmers. In addition, farmers' reaction to such policy actions should be accurately anticipated as well as the side effects of such policy actions. Such knowledge may be gained from farm level studies using programming techniques.

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[1] Henderson, J.M. and Quandt, R.E. Microeconomic Theory: A Mathematical Approach. McGraw Hill Book Company, 1971.

Earlier chapters of this study have provided a descriptive accounts of farmers' resource supply position and the allocation of these resources among alternative enterprises. Chapter IV estimated a positive supply (acreage) response of cowpea from time series data. Because the response is based on historical data, it is only accurate in describing the past and can only predict the future accurately if past policies and relationships among variables remain stable. This is a major drawback of all positive analyses.

The present chapter makes the normative assumption of profit maximization on the part of the farmers studied and uses the tool of static Linear Programming (LP) to design optimal farm plans for the farmers. Firstly, a brief discussion of the LP technique is provided and the concept of a 'representative farm' discussed. Summaries of the characteristics of representative farms used and the Simplex Tableaux are then given. This is followed by the presentation and discussion of the resulting optimal farm plans accompanied by results of the policy simulations including parametric alteration of cowpea prices from which a normative cowpea supply response is estimated. A brief comparison is made between the latter and the positive supply response of chapter IV. The chapter ends with concluding remarks.

Linear Programming Technique, Limitations and Justification for Use

Among the most widely used tools of analysis in production economics are marginal analysis, budgeting and mathematical programming. They all have some essential features in common. In marginal analysis the variable to be maximized is stated as a continuous function of the explanatory variables with continuous first and second order partial derivatives and the profit maximization point is obtained by equating marginal revenue to marginal cost. This is also the point of zero marginal profit. Farm budgeting is an appraisal of possible changes in cost and returns in a given time period when there is a contemplated change in the use of farming resources. Depending upon the specific objectives at hand budgeting procedures use economic principles to determine optimum levels of farming intensity, least cost methods of production and profit maximizing enterprise combination. The only basic difference between LP and budgeting is that the former is more sophisticated and automatically guarantees a unique optimal solution. It replaces the continuous production function in both marginal analysis and budgeting with a finite number of independent linear activities and it is able to handle inequalities in resource supplies. Thus Dorfman et al, argue that ... "apart from handling inequality conditions of resource supplies there does not appear to be any other difference between LP and marginal analysis appropriately tailored to the case of finite number of activities."[1]

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[1] See Dorfman R., Samuelson, P. and Solow R. Linear Programming and Economic Analysis. New York: McGraw Hill Book Co., 1958, p. 133.

Linear Programming is a mathematical technique for maximizing or minimizing a linear objective function subject to some constraints in the form of linear inequalities. A standard LP problem (the Primal)[1] may be stated mathematically as follows:

$$\text{Max } f(Z) = \pi = \sum_{j=1}^{n} P_i Z_j - \sum_{j=1}^{n} \sum_{i=1}^{m} C_{ij} K_{ij} \; \ldots\ldots\ldots \; (1)$$

Subject to:

$$\sum_{i=1}^{m} Q_{ij} Z_j \leq A_i \quad (i=1 \;\ldots\ldots\; m)$$

$$Z_j \geq 0 \quad (j=1 \;\ldots\ldots\; n) \quad \ldots\ldots\ldots\ldots\ldots\ldots \; (2)$$

Where the object is to find the vector $Z(Z_i \ldots Zn)$ which maximizes the objective function Max $f(Z) = \pi$.

Where π = net profit (surplus) to fixed inputs

P_i = gross margin per unit of jth enterprise

Z_j = decision variable, e.g., acreage of jth enterprise

C_{ij} = cost per unit of ith input used in the operation of jth enterprise

K_{ij} = quantity of ith variable input used in jth enterprise

Q_{ij} = requirement of ith resource for one unit of jth enterprise

A_i = total supply of ith resource avaiable (to the farmer).

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[1] Associated with the Primal LP problem given by equations (1) and (2) there exists the dual LP problem where the object is to find the vector, say $Y = (y_i \ldots y_n)$ which minimizes the objective function given by Min $G(y) - A_iY_j{}^1$ subject to

$$Q_{ij}y_j \geq P_i$$

$$y_j \geq 0$$

For the discussion of the importance of the duality relationship see Bamoul, W.J. Economic Theory and Operations Analysis, 4th ed., Englewood Cliff, N.J.: Prentice-Hall Inc., 1977 and Sengupta, J.R. and Fox, K.A. Optimization Techniques in Quantitative Economic Model. Amsterdam: North Holland Publishing Co., 1969.

The application of LP in production economic research has been well demonstrated.[1] In particular its application to farm planning has generally been to determine farm plans for 'typical' or model farm resource situations. However, as a tool, it has application in any economic situation where the following trinity of conditions exist:

(i) the existence of a quantifiable objective to be optimized.

(ii) the existence of alternative means of attaining the objective function and

(iii) the existence of limitations (physical, institutional, etc.) for attaining the objective.

Although these conditions make the application of LP almost universal, the standard LP model operates under the following restrictive assumptions:

(i) additivity of resources and activities which implies the absence of technological externalities in production or in other words, independence of production processes and of activities.

(ii) proportionality of activity levels to resources. This assumption precludes diminishing and increasing returns in production and implies that production activities are homogeneous of degree one in all factor inputs (i.e. production functions are linearly homogeneous).

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[1] For a brief survey of LP studies see 'On Economic Optimization, A Non-technical Survey.' Day, R. H. in A Survey of Agricultural Economics Literature, Vol. 2, ed. Judge, G.G., Day, R.H. et al., pp. 57 - 92, and An Investigation of the Application of Programming Techniques to Farm Managment Problems. MacHardy, F.V., Ph.D. Thesis, University of Edinburgh, 1964, (Unpublished).

(iii) The standard LP model is deterministic with single valued expectations. The implication is that input-output coefficients, resource supplies, costs and prices are all known with certainity.

(iv) Divisibility of activities and resources and non-negativity of decision variables are also assumed by the standard LP model.

Although restrictive, these assumptions are not considered to create serious difficulties for the use of the Technique in the present study. Firstly, farms in the area studied are rarely large enough (see Table 11) to attain economics of scale in resource utilization - hence the assumption of proportionality may not be violated. While technological externalities may be experienced in agricultural production (e.g. in the combination of turkey and poultry enterprises or from residual effects of fertilizers and pesticides) they are rare in traditional agriculture. The farmers studied used no fertilizers or chemical pesticides and the existing crop combinations are those that have been time-tested. It is therefore safe to suppose that no technological externalities are experienced in the cropping systems in the area studied. The beneficial effects of cowpea on other crops in the rotation are ignored in this study because of the lack of data to quantify such benefits.

Perhaps the most valid restriction of the tool in the current context is the assumption of constancy or certainity of technological coefficients and of input and output prices, etc. Clearly under the conditions of variable rainfall, the input-output coefficients are bound to vary and so are the output prices. Farmers' behaviour is also a highly uncertain variable in agricultural production.[1] Risk and uncertainity from these sources are dealth with in the next chapter and do not minimize the usefulness and justification of LP in this study. Even so, allowance is made, inspite of the profit maximization assumption, for some staples to be incorporate where feasible into the optimum plans to cater for a minimum level of self-sufficiency.

The Representative Farm Firm-Concept

It would be ideal to build a model for each individual farm studied because each farm is unique but such an exercise is expensive and inefficient. The alternative is to classify sample farms into homogeneous groups and to construct the so-called 'benchmark' or 'representative farm' for each group by averaging out the characteristics of farms in the respective groups. While such an exercise may lead to bias and a loss of precision it has considerable merit.

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[1] See Johnson, D. Gale. Forward Prices for Agriculture. Chicago, Illinois: University of Chicago Press, 1965 Stainforth, S.D. "Combating Uncertainity in Agricultural Production" Journal of Farm Economics, Vol. 36, No. 1, pp. 87 - 97 and Schickle, R. "Farmers' Adaptation to Income Uncertainity" Journal of Farm Economics, Vol. 39, No. 3, August 1950, pp. 356 - 374.

The concept of the representative firm or farm is an old concept[1] and a subject of a long standing controversy in production economics. Elliot defined a typical farm as "... a model farm in the frequency distribution of farms from the same universe; or it is a farm which is representative of a group of farmers who are doing essentially the same thing."[2] He was the first to apply the concept to the farm situation and to use quantitative procedures to sort farms into size groups and to determine the typical organization within each group. Since then, Frick and Andrews[3] have compared the following four methods of classification in a sample of 51 farms in estimating a farm supply function: -

(i) mean of the resources

(ii) classification according to farm sizes

(iii) grouping farms on the basis of the most limiting resources (i.e., the Homogeneous Restriction method)

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[1] Alfred Marshall defined a representative firm as "one which is managed with normal ability and which has normal access to the economies, external or internal which belong to the aggregate volume of production, account being taken of the class of goods produced the condition of marketing them and the economic environment generally" --- see Marshall, Alfred. Principles of Economics, 8th ed. London: MacMillan and Co. Ltd., 1920, pp. 317.

[2] See Elliot, F.F. The Representative Firm Idea Applied to Research and Extension in Agricultural Economics; Journal of Farm Economics, Vol. 10, No. 4, October, 1928, pp. 486 - 498.

[3] See Frick, G.E. and Andrew, R.A. Aggregation Bias and Four Methods of Summing Farm Supply Function; Journal of Farm Economics, Vol. 47, No. 3, August, 1965, pp. 696 - 700.

(iv) grouping farms according to potential size.

Their conclusion was that the homogeneous restriction method resulted in the least amount of bias. Day used the duality theorem to show that under conditions of technological homogeneity and proportional prices, one sufficient condition for eliminating aggregation bias is that all farms within a group should have the same ratio of one resource to another.[1]

Clearly divergent viewpoints exist on the subject of representative farms and the methods of arriving at such farms within a given sample.[2] The following conclusions may be made from the literature on the subject: -

(i) that no definitive or unique procedure exists for deriving representative farms although the following methods are most widely used (a) average resource method, (b) the most limiting resource method and (c) resource ratio method

(ii) that the method used depends upon the purpose of the particular study and

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[1] See Day, R.H. "The Aggregation Problem of LP Model of Production Response" Journal of Farm Economics, Vol. 47, No. 3, August, 1965, pp. 681 - 695.

[2] For many different view points see Day, L.M. 'Use of Representative Farm in Studies of Inter-regional Competition and Production Response' Journal of Farm Economics, Vol. 45, No. 5, Dec. 1963, pp. 1438 - 1447. Carter, Harold O. 'Representative Farms --Guides for Decision Making' Journal of Farm Economics, Vol. 45, No. 5, Dec., 1963, pp. 1448 - 1455 and Beker, M.H. 'Representative Farms --Guides for Decision Making' Journal of Farm Economics, Vol. 45, No. 5, Dec., 1963, pp. 1455 - 1457.

(iii) that while the representative farm technique leads to some aggregation bias with diversified commercial farms, it is an efficient way of handling problems of resource allocation and farm policy in low income and less diversified areas with low degree of commercialization.

In this study all farms in one district are considered to form one homogeneous group. Thus seven representative farms are constructed in the study, one for each district. The reason for this is that the average 'quantity' of land (the most restrictive resource) available per holder is different for each district (see Table 5) as is the potential amount of family labour resource (see Table 6). As well, the average farm sizes differ from district to district and so are the average gross returns per capita (from crop farming) and the returns from livestock enterprises (see Table 11 and Appendix Table 6 respectively). The latter two provide indications of tne financial (or capital) standings of the farmers. The classification also takes account of the differences in the technology of farming and the prevailing cropping patterns. It therefore conforms to the homogeneous restriction -- or most limiting resource and average resource methods of classification and will accordingly minimize the amount of bias if any.

Characteristics of the Representative Farms

The resource endowment of the sampled farmers in each of the seven districts and the input-output coefficients of the enterprises were averaged out to construct the representative farms. The characteristics of these farms were derived in Chapter IV but are summarized in Table 14 for brief discussion.

Table 14

Summary of the Characteristics of Representative Farms

District	LAND (ACRES) Total Available	Average Cultivated 1975-78	Total Available Family Labour (Man-days per month)	Working Capital ¢
Wa	37.2	9.3	86	444.0
Lawra	22.1	10.0	131	510.0
Tumu	31.8	17.1	80	421.0
Sandama	20.6	4.0	84	315.00
Navrongo	12.2	4.0	62	120.0
Bolgatanga	4.1	2.2	84	233.0
Bawku	16.3	8.0	101	220.0

Land Constraint

The quantification of land as a resource constraint in this study has two major difficulties. Firstly, land resource in each district is deemed to be of equal quality (or productivity). In other words land has been treated as a homogeneous resource implying that productivity is the same in each given district. Clearly this is unlikely, yet the lack of sufficient information precludes classification of land according to the degree of soil fertility and other characteristics. Secondly, the system of land rotation practised by farmers necessities that substantial proportion of total available land resource be left idle to regenerate fertility. Consequently, the 'quantity' of unfarmed land resource in a given season is not a sufficient index of land surplus. Bearing this in mind, the average quantity of land resource utilized in 1975-78 is used as the base of land constraint. This is then varied up to 50% of total available land resource,where appropriate,under the assumption that under the prevailing system of farming at leat 50% of land resource should be under fallow at any given time.

Labour Constraint

Family labour is the most widely used labour resource in the region but exchange labour is also widespread. Under exchange labour, which is analogous to cooperation, two or more farmers band together to work for each other on reciprocal basis. The system is helpful to farmers in enabling them to execute promptly operations which require timeliness. However, it is not taken into account in the LP programmes. This is because exchange labour has the same economic effects as family labour and does not increase the effective man-days of labour available to the farmer. Instead allowance is made in the programme for hired labour to be used at the going wage rate of ¢4.00 per man-day to supplement family labour where necessary.

Seasonality of rainfall perforces seasonality in the demand for labour for cropping enterprises. Furthermore, within the cropping season (April - December) wide fluctuations occur with respect to the flow in the demand for labour. The timeliness with which operations like planting and harvesting have to be executed accentuates these fluctuations.[1] Under such circumstances farmers may face labour shortages inspite of a high potential family labour availability.

Table 15 provides the cropping calendar of the region. The table shows that the demand for labour is highest in the months of March - April, and May - June when land preparation and planting are done and September - October and November - December when harvesting is done.

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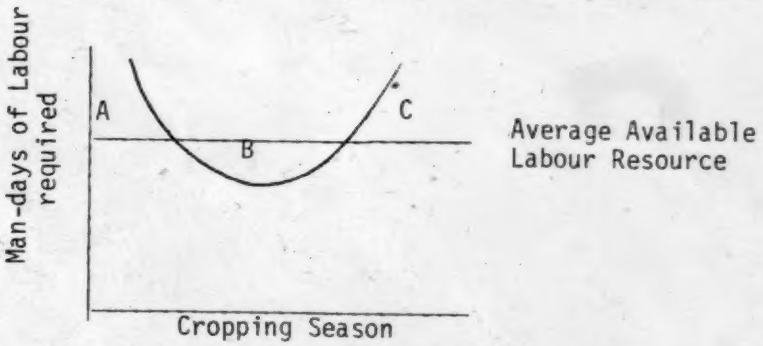
[1] The situation may be illustrated diagrammatically as follows:


Man-days of Labour required
A
B
C
Average Available Labour Resource
Cropping Season

Where:
A = land preparation and planting period
B = period for weeding and mound repairs
C = harvesting period

These months are therefore taken as the months in which available family labour resource may be most constraining.

Table 15*

Crop Calendar for Upper Region

Period	Operations/Activities	Crops
1. Western Sector		
March-April	land prepartion	Groundnut, Bambara, Millet, Sorghum, Maize, Rice
	Planting	Yams
May-June	Planting	Groundnut, Bambara, Millet, Sorghum, Maize, Rice
July-August	Weeding, thinning and mound repairs	all crops
August-September	Harvesting	Maize, 1st. Yams, early Millet
October-November	Harvesting	Groundnut, Bambara, Maize, Sorghum, Rice, late Millet
December	Harvesting	2nd. Yams
2. Eastern Sector		
March-May	Land prepartion	all crops
June-July	Planting	all crops
July-August	Weeding, thinning, ridge repairs	all crops
August-September	Harvesting	all crops, early millet
September-October	Harvesting	groundnut, Bambara, Cowpea, Sorghum
November-December	Harvesting	Late Millet, Rice, Cowpea

*Sources:

1. Survey data.
2. See LARC op. cit., p. 17.
3. Land and Water survey in the Upper and Northern Regions, FAO/SF:11/GHA., Vol. IV, Agronomy and Sociology, Rome, 1968, p. 24.

Capital Constraint

The lack of capital appears to be the most obvious constraint to the increased development of traditional agriculture. Nonetheless, quantification of this constraint is usually elusive. Attempts were made in this study to assess the amount of working capital expended by farmers through specific questions put to them to provide details of hired labour other purchased inputs and kind payments made for services. The average of estimates thus obtained are given in Table 14 and are used as working capital constraints. In addition, allowances were made for borrowable capital of up to the value of the working capital expended from own resources. An interest rate of 15 per cent is charged per unit of borrowed capital.[1] The amounts of borrowable capital are later varied to investigate effects of granting credit facilities on farm production and incomes.

Self-Sufficiency in Food Production

It is generally recognised that apart from the physical inputs of land, labour and working capital, agricultural productivity and growth can be constrained by malnutrition.[2] Provision is therefore made in the programme to produce the family requirement of foodstuffs for adequate nutrition. The purpose of incorporating self-sufficiency (in food production) in the model are three fold --- namely (i) to produce optimum plans close enough to reality (to plans actually practised) to facilitate adaption (ii) to ascertain how self-sufficiency (autarky) as an agricultural policy is comparable with profit maximization and (iii) to ascertain what crops will be profitable under autarkic conditions.

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[1] The statutory interest rate is 7½% for agricultural credit. This is doubled here to reflect that costs of arranging for and obtaining a loan from the established banking system.

[2] Malnutrition is defined here to mean faulty or inadequate nutrition.

Table 16 gives the annual staples requirements per average size family in the districts. It should be emphasized that the figures exclude meat, fish, eggs, fruits, leafy vegetables and shea butter which also feature prominently in the diets of the people. The table was derived from survey data provided by the FAO and the Ministry of Agriculture in 1968 and 1976. Millet and sorghum have been substituted for rice, maize and yams in the districts where the latter are not cultivated in appreciable quantities. The substitution rates used were based on calorific contents of the raw products. Although the data presented in the table do not take into account the methods of food preparation, in addition to the other foods mentioned above they should provide adequate year round nutrition for the people.

Technical Coefficients

The input-output coefficients used in the programme are those derived in Appendix Table 8:1-8:11. They were obtained from the cross-sectional survey data and correspond very closely with data held

Table 16*

Annual Staple Foods Requirement per Family by District (lbs)

Staples	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku
Millet and Sorghum	3900	4860	4196	4139	4154	5817	5145
Maize	710	875	--	--	--	--	--
Yam	350	438	--	--	--	--	--
Rice	210	268	--	178	--	--	--
Groundnut	570	790	570	580	440	580	680
Cowpea	340	475	330	340	260	343	405
Bambara	177	247	170	180	130	180	210
Av. Family Size	8	10.8	7.5	7.7	5.9	7.8	9.2

*Source: Land & Water Survey in the Upper & Northern of Ghana- Final Report, Vol. 1 - General. FAO/SF: 31/GHA-6 Rome, 1968.
Appraisal of Upper Region Agricultural Development Project - Ghana World Bank Report No. 1601A-GH, June, 1976.
Agricultural Commodity Projections 1970-80. Vol. 11 FAO Rome, 1971, p. 32.

by the Ministry of Agriculture. The price data used in the computation were the farm-gate prices quoted to the farmers at harvesting time. The use of these prices has the following advantages. Firstly, they are the prices actually received by the farmers and therefore the only ones relevant in their production decisions. Secondly, their use eliminates the complication from price differentials brought about by differences in storage methods and lengths of storage period.

It is acknowledged that ordinarily the prices at which the farmer will purchase his residual/additional requirements of food from the open market will be higher than the prices at which he sells his surpluses at harvest time. However, since such purchases will occur at discrete time periods (i.e., as the need arises) the purchase prices per unit will be no means be uniform. To simplify the issue, it is assumed in the programme that farmers know their annual requirements of food with certainity and make good their deficits at harvest time when prices are lowest. Their sale and purchase prices are therefore the same. Appendix Table 10 gives the average farm-gate prices of the various products by district.

Optimum Profit Programming Results

Tables 17 - 23 give the problem matrices (simplex Tableaux) for the representative farms by district. The problems were solved with the MPSG/360 IBM package.

Table 24 summarises optimum Profit Plan I for the representative farms. The plan uses the average quantities of land utilized in 1975 - 78 seasons as land constraint and incorporates the need for

Table 17**

LP Problem Matrix (Simplex Tableau) For the Representative Farm - Wa District

CONSTRAINTS	RHS		ACTIVITIES											Buying								Selling								Family Subsistence									
			Gc-Ma-M	Gc-Ma	YAM	BAM-GN	MAIZE	COWPEA	MILLET	G-CORN	RICE	M-Gc-Cow-Ma	G-NUT	G-CORN	MAIZE	COWPEA	MILLET	YAM	BAM	G-NUT	RICE	G-CORN	MAIZE	COWPEA	MILLET	YAM	BAM	G-NUT	RICE	F G-CORN	F MAIZE	F COWPEA	F MILLET	F YAM	F BAM	F G-NUT	F RICE	BOMCAP	HIRE-L
LAND (ACRES)	9.3	L	1	1	1	1	1	1	1	1	1	1	1																										
M-AML (HD)	172.0	L	10	10	20	10	10	10	10	10	11	10	10																										-1
M-JJL (HD)	172.0	L	4	4	8	4	3	3	3	3	3	4	3																										-1
J-AFL (HD)	172.0	L	14	14	18	10	10	10	10	10	14	14	10																										-1
PTOCTPZ (HD)	172.0	L	8	6	15	10	10	4	8	8	8	6	8																										-1
N-DFL (HD)	172.0	L	4	5	8	8	8	2	10	10	8	4	6																										-1
G-CORN	0	L	-310	-430						-400		-300		-1								1								1									
MAIZE	0	L	-320	-400			-420					-300			-1								1								1								
COWPEA	0	L						-320				-70				-1								1								1							
MILLET	0	L	-470						-400			-250					-1								1								1						
YAM	0	L			-3300													-1								1								1					
BAMBARA	0	L				-250													-1								1								1				
G-NUT	0	L				-200							-400							-1								1								1			
RICE	0	L									-750										-1								1								1		
Z MAX		N												-.29	-.21	-.30	-.36	-.22	-.42	-.33	-.24	.29	.21	.30	.36	.22	.42	.33	.24									-0.75	-4.00
OPCA P	6440.0	L	5.00	7.00	130.00	22.00	3.00	4.00	3.00	3.00	15.00	4.00	20.00																									-1	
BORCAP	6440.0	L																																				-1	
F G-CORN (lb)	1300.0	G																												1									
F MAIZE (lb)	773.0	G																													1								
F COWPEA (lb)	340.0	G																														1							
F MILLET (lb)	2620.0	G																															1						
F YAM (lb)	352.0	G																																1					
F BAMBARA (lb)	177.0	G																																	1				
F G-NUT (lb)	570.0	G																																		1			
F RICE (lb)	201.0	G																																			1		

**Where:

M-AFL is March -- April family labour

M-JFL is May -- June family labour

J-AFL is July -- August family labour

PTOCTFL is September -- October family labour

G-Corn is Guinea Corn

G-Nut is Groundnut

OPCAP is (own source) working capital

BORCAP is borrowed capital

Gc is Guinea corn, Ma is Maize, M is Millet, GN is Groundnut

Bam is Bambara beans, Cow is Cowpea, S is Sorghum[1]

Hire-L is hired labour

MD is Man-days of labour

FG-Corn is family requirement of Guinea Corn

FMaize is family requirement of Maize

FCowpea is family requirement of Cowpea

FMillet is family requirement of Millet

FYam is family requirement of Yam

FBambara is family requirement of Bambara

FG-Nut is family requirement of Groundnut

FRice is family requirement of Rice

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[1] Sorghum and Guinea corn are used interchangeably in this study.

Table 18

LP Problem Matrix (Simplex Tableau) For the Representative Farm - Lawra District

			Gc-Mu-M	Gc-Mu	YAM	BAM-GN	MAIZE	COWPEA	MILLET	G-CORN	RICE	M-Gc-Cow-Mu	G-NUT	G-CORN	MAIZE	COWPEA	MILLET	YAM	BAM	G-NUT	RICE	G-CORN	MAIZE	COWPEA	MILLET	YAM	BAM	G-NUT	RICE	F G-CORN	F MAIZE	F COWPEA	F MILLET	F YAM	F BAM	F G-NUT	F RICE	BORCAP	HIRE-L
LAND (ACRES)	10.0	≥	1	1	1	1	1	1	1	1	1	1	1																										
M-APL (MD)	262.0	≥	10	10	20	10	10	10	10	10	11	10	10																										-1
M-JPL (MD)	262.0	≥	4	4	8	4	3	3	3	3	3	4	3																										-1
J-APL (MD)	262.0	≥	14	14	18	10	10	10	10	10	14	14	10																										-1
PTOCTPL(MD)	262.0	≥	6	6	13	10	10	4	8	8	8	6	8																										-1
M-DPL (MD)	262.0	≥	4	5	8	6	6	2	10	10	6	4	6																										-1
G-CORN	0	≥	-310	-410						-400		-300		-1								1								1									
MAIZE	0	≥	-300	-420			-420					-300			-1								1								1								
COWPEA	0	≥						-320				-70				-1								1								1							
MILLET	0	≥	-270						-550			-250					-1								1								1						
YAM	0	≥			-3000													-1								1								1					
BAMBARA	0	≥				-250													-1								1								1				
G-NUT	0	≥				-250							-400							-1								1								1			
RICE	0	≥									-750										-1								1								1		
Z MAX		=												-.29	-.21	-.30	-.36	-.22	-.42	-.53	-.24	.29	.21	.30	.36	.22	.42	.53	.24									-0.15	-4.0
OPCAP	¢510.0	≥	5.00	7.00	132.00	22.00	3.00	4.00	3.00	3.00	11.00	4.00	20.00																									-1	
BORCAP	¢300.0	≥																																				-1	
F G-CORN (lb)	1620.0	≤																												1									
F MAIZE (lb)	875.0	≤																													1								
F COWPEA (lb)	475.0	≤																														1							
F MILLET (lb)	3240.0	≤																															1						
F YAM (lb)	430.0	≤																																1					
F BAMBARA (lb)	247.0	≤																																	1				
F G-NUT (lb)	230.0	≤																																		1			
F RICE (lb)	268.0	≤																																			1		

Table 19

LP Problem Matrix (Simplex Tableau) For the Representative Farm - Tumu District

			GC-M-CO	GN-BAM	MILLET	G-CORN	COWPEA	G-NUT	MILLET	G-CORN	COWPEA	G-NUT	BAMBARA	MILLET	G-CORN	COWPEA	G-NUT	BAMBARA	F MILLET	F G-CORN	F COWPEA	F G-NUT	F BAMBARA	BORCAP	HIRE-L
LAND (ACRES)	17.1	≥	1	1	1	1	1	1																	
M-AFL (MD)	160.0	≥	10	10	10	10	10	10																	-1
M-JFL (MD)	160.0	≥	3	3	3	3	2	4																	-1
J-AFL (MD)	160.0	≥	12	8	10	10	8	8																	-1
PTOCTFL (MD)	160.0	≥	7	10	0	0	3	8																	-1
N-DFL (MD)	160.0	≥	3	7	9	9	2	7																	-1
MILLET	0	≥	-220		-630				-1					1					1						
G-CORN	0	≥	-250			-570				-1					1					1					
COWPEA	0	≥	- 70				-250				-1					1					1				
G-NUT	0	≥		-320				-500				-1					1					1			
BAMBARA	0	≥		-180									-1					1					1		
Z MAX		=							-.34	-.30	-.28	-.49	-.42	.34	.30	.28	.49	.42						-0.15	-4.00
OPCAP	¢420.0	≥	5.00	22.00	3.60	3.50	4.00	20.00																-1	
BORCAP	¢400.0	≥																						-1	
F MILLET	2707.0	≤																	1						
F G-CORN	1399.0	≤																		1					
F COWPEA	330.0	≤																			1				
F G-NUT	570.0	≤																				1			
F BAMBARA	170.0	≤																					1		

Table 20

LP Problem Matrix (Simplex Tableau) For the Representative Farm - Sandama District

			GC-M-COW	MILLET	G-CORN	G-NUT	RICE	COWPEA	GN-BAM	MILLET	G-CORN	COWPEA	G-NUT	BAM	RICE	MILLET	G-CORN	COWPEA	G-NUT	BAM	RICE	F MILLET	F G-CORN	F COWPEA	F G-NUT	F BAM	F RICE	BORCAP	HIRE-L
LAND (ACRES)	4.0	≥	1	1	1	1	1	1	1																				
M-AFL (MD)	168.0	≥	8	8	8	10	11	8	10																				-1
M-JFL (MD)	168.0	≥	4	3	3	4	3	2	4																				-1
J-AFL (MD)	168.0	≥	14	10	10	8	14	8	8																				-1
PTOCTFL (MD)	168.0	≥	6	6	6	8	8	3	9																				-1
N-DFL (MD)	168.0	≥	3	3	3	7	6	2	6																				-1
MILLET	0	≥	-240	-620						-1						1						1							
G-CORN	0	≥	-200		-570						-1						1						1						
COWPEA	0	≥	-90					-270				-1						1						1					
G-NUT	0	≥				-300			-420				-1						1						1				
BAMBARA	0	≥							-180					-1						1						1			
RICE	0	≥					-750								-1						1						1		
Z MAX		N								-.37	-.35	-.28	-.50	-.39	-.24	.37	.35	.28	.50	.39	.24							-.15	-4.00
OPCAP	¢300.0	≥	5.00	3.60	3.60	24.00	3.00	4.00	27.00																			-1	
BORCAP	¢300.00	≥																										1	
F MILLET (lb)	2793.0	≤																				1							
F G-CORN (lb)	1046.0	≤																					1						
F COWPEA (lb)	340.0	≤																						1					
F G-NUT (lb)	560.0	≤																							1				
F BAMBARA (lb)	180.0	≤																								1			
F RICE (lb)	178.0	≤																									1		

Table 21

LP Problem Matrix (Simplex Tableau) For the Representative Farm - Navrongo District

			MILLET	G-CORN	G-NUT	COWPEA	ELM-CC-COW	GN-BAM	LM-CC-COW	MILLET	G-CORN	COWPEA	G-NUT	BAMBARA	MILLET	G-CORN	COWPEA	G-NUT	BAMBARA	F MILLET	F G-CORN	F COWPEA	F G-NUT	F BAMBARA	BORCAP	HIRE-L
LAND (ACRES)	4.0	≥	1	1	1	1	1	1	1																	
M-AFL (MD)	124.0	≥	10	10	11	10	11	11	10																	-1
M-JFL (MD)	124.0	≥	3	3	3	2	3	4	3																	-1
J-AFL (MD)	124.0	≥	10	10	8	8	12	8	12																	-1
PTOCTFL (MD)	124.0	≥	0	0	10	3	4	10	4																	-1
N-DFL (MD)	124.0	≥	10	10	4	2	6	6	6																	-1
Z MAX		N								-.33	-.32	-.26	-.48	-.40	.33	.32	.26	.48	.40						-0.15	-4.00
MILLET	0	≥	-620				-580		-380	-1					1					1						
G-CORN	0	≥		-550			-150		-240		-1					1					1					
COWPEA	0	≥				-270	-100		-150			-1					1					1				
G-NUT	0	≥			-660			-360					-1					1					1			
BAMBARA	0	≥						-170						-1					1					1		
OPCAP	¢120.0	≥	3.80	3.60	20.00	4.00	5.00	22.00	5.00																-1	
BORCAP	¢120.0	≥																							1	
F MILLET (lb)	2769.0	≤																		1						
F G-CORN (lb)	1355.0	≤																			1					
F COWPEA (lb)	260.0	≤																				1				
F G-NUT (lb)	440.0	≤																					1			
F BAMBARA (lb)	130.0	≤																						1		

Table 22

LP Problem Matrix (Simplex Tableau) For the Representative Farm - Bolgatanga District

			MILLET	G-CORN	G-NUT	COWPEA	GC-M-COW	GN-BAM	M-COW	MILLET	G-CORN	COWPEA	G-NUT	BAMBARA	MILLET	G-CORN	COWPEA	G-NUT	BAMBARA	F MILLET	F G-CORN	F COWPEA	F G-NUT	F BAMBARA	BORCAP	HIRE-L
LAND (ACRES)	2.2	≥	1	1	1	1	1	1	1																	
M-AFL (MD)	160.0	≥	7	7	9	7	7	9	7																	-1
M-JFL (MD)	168.0	≥	3	3	3	2	3	4	3																	-1
J-AFL (MD)	168.0	≥	8	8	8	8	10	8	10																	-1
PTOCTFL (MD)	168.0	≥	3	3	7	2	4	8	4																	-1
N-DFL (MD)	168.0	≥	5	5	9	4	7	10	7																	-1
MILLET	0	≥	-635				-580		-400	-1					1					1						
G-CORN	0	≥		-558			-240				-1					1					1					
COWPEA	0	≥				-320	-150		-220			-1					1					1				
G-NUT	0	≥			-600			-240					-1					1					1			
BAMBARA	0	≥						-350						-1					1					1		
Z MAX		=								-.36	-.32	-.34	-.51	-.41	.36	.32	.34	.51	.41						-0.15	-4.00
OPCAP	¢230.0	≥	11.60	11.50	32.00	12.00	21.00	45.00	12.00																-1	
BORCAP	¢230.0	≥																							1	
F MILLET (lb)	4363.0	≤																		1						
F G-CORN (lb)	1454.0	≤																			1					
F COWPEA (lb)	340.0	≤																				1				
F G-NUT (lb)	580.0	≤																					1			
F BAMBARA(lb)	190.0	≤																						1		

Table 23

LP Problem Matrix (Simplex Tableau) For the Representative Farm - Bawku District

			MILLET	G-CORN	G-NUT	COWPEA	M-GC-COW	GN-BAM	M-COW	MILLET	G-CORN	COWPEA	G-NUT	BAMBARA	MILLET	G-CORN	COWPEA	G-NUT	BAMBARA	F MILLET	F G-CORN	F COWPEA	F G-NUT	F BAMBAR.	BORCAP	HIRE-L
LAND (ACRES)	8.0	≥	1	1	1	1	1	1	1																	
M-AFL (MD)	202.0	≥	4	4	5	4	4	5	4																	-1
M-JFL (MD)	202.0	≥	2	2	3	2	3	4	3																	-1
J-AFL (MD)	202.0	≥	8	8	8	8	10	8	10																	-1
PTOCTFL (MD)	202.0	≥	3	3	7	6	3	10	3																	-1
N-DFL (MD)	202.0	≥	5	5	9	2	7	7.	7																	-1
MILLET	0	≥	-610				-590		-400	-1					1					1						
G-CORN	0	≥		-570			-240				-1					1					1					
COWPEA	0	≥				-320	-150		-200			-1					1					1				
G-NUT	0	≥			-660			-360					-1					1					1			
BAMBARA	0	≥						-240						-1					1					1		
Z MAX		N								-.36	-.31	-.32	-.49	-.40	.36	.31	.32	.49	.40					+0.15	-4.00	
OPCAP	¢220.0	≥	3.60	3.50	24.00	4.00	5.00	27.00	6.00															-1		
BORCAP	¢220.0	≥																						1		
F MILLET (lb)	3432.0	≤																		1						
F G-CORN (lb)	1715.0	≤																			1					
F COWPEA (lb)	405.0	≤																				1				
F G-NUT (lb)	630.0	≤																					1			
F BAMBARA(lb)	210.0	≤																						1		

Table 24

Optimum Profit Plans I by District

	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku
Land Used (Acres)	9.3	10.3	17.1	4.0	4.0	2.2	8.0
Allocation (Acres)	2.7 Ma-S-M 6.6 Yam	2.4 Ma-S-M 7.6 Yam	17.1 Gn	4.0 Gn-Bam	4.0 Gn	2.2 E^1+Lm-S-Cow	8.0 E+Lm^1-S-C
Crop Production (lb)							
Millet	739.0	659.06				1276.0	4720.0
Sorghum	848.47	756.70				528.0	1916.0
Cowpea	-	-				330.0	1200.0
Groundnut	-	-	8550.0	1680.0	2640.0	-	-
Bambara	-	-	-	720.0	-	-	-
Yam	19688.98	22677.17	-	-	-	-	-
Maize	821.10	732.28	-	-	-	-	-
Rice	-	-	-	-	-	-	-
Crops Purchased (lb)							
Millet	1861.01	2580.94	2797.0	2793.0	2769.0	3087.0	-
Sorghum	451.53	863.31	1399.0	1346.0	1385.0	926.0	-
Cowpea	340.0	475.0	330.0	340.0	260.0	13.0	-
Groundnut	570.0	790.0	-	-	-	580.0	680.0
Bambara	177.0	247.0	170.0	-	130.0	180.0	210.0
Yam	-	-	-	-	-	-	-
Maize	-	142.70	-	-	-	-	-
Rice	210.0	268.0	-	178.0	-	-	-
Crop Surpluses/ Sold (lb)							
Millet	-	-	-	-	-	Nil	1290.0
Sorghum	-	-	-	-	-	-	205.0
Cowpea	-	-	-	-	-	-	795.0
Groundnut	-	-	7980.0	1100.0	2200.0	-	-
Bambara	-	-	-	540.0	-	-	-
Yam	19338.98	22239.17	-	-	-	-	-
Maize	111.1	-	-	-	-	-	-
Rice	-	-	-	-	-	-	-
Net Profit	¢2778.13	¢2878.89	¢2325.12	-¢ 881.83	-¢ 420.57	-¢1799.66	¢365.10

[1] E + Lm = Early and Late Millet

autarky (self-sufficiency) in food production. The table shows that to maximize net revenue with 9.3 acres of land, farmers in the Wa district should allocate 2.7 acres to maize-millet-sorghum (as mixed enterprise or intercrop) and 6.6 acres to pure crop yams. The combination will yield for sale surpluses of 19339.98 lbs (8.6 long tons) and 111.1 lbs (0.05 tons) respectively of yams and maize over domestic requirements. All the family requirements of rice, cowpea, groundnuts and bambara would be satisfied from purchases made on the open market. The net profit from all operations including transactions on the open market would be ¢2778.13.

The optimum profit plan for Lawra district consists of 2.4 acres of maize-millet-sorghum mixed enterprise and 7.6 acres pure crop yams. The net profit from the plan after catering for all domestic food requirements is ¢2878.89. In the Tumu district the maximum profit plan involves the investment of all resources in groundnut (pure-crop) cultivation. This yields 8550 lbs (3.8 tons) of marketed surplus. All other foods are purchased from the open market and the plan generates ¢2325.12 net profit (see Table 24). Similarly the representative farm for the Bawku district would generate a net profit of ¢365.10 from the optimum plan which involves the allocation of all 8 acres of land to early-late millet-sorghum-cowpea (mixed-enterprise). In the cases of Sandama, Navrongo and Bolgatanga districts Table 24 shows that if provision is made for year-round food requirements the optimum profit farm plans yield net deficits of ¢881.83, ¢420.57 and ¢1799.66 respectively. In other words they are food deficit districts[1] under the assumptions of the plan. Farmers in these districts can not produce enough food to feed their families if they allocate the resources available to them optimally (to maximize net returns) among existing crop enterprises. These deficits may be satisfied with purchases made with proceeds derived from the sale of livestock and with imports from the south.

Optimum Profit Plans and Actual Plans in Practice

The optimum profit plans and the actual plans adopted by the farmers provide an interesting comparison. Table 25 provides a comparison of net revenues from the two plans. Allowances have been made to incorporate in the actual plans the same quantities of foods required by the family and at the same prices as the optimum plans. Table 25 shows that the optimum profit plans generate higher net revenues than the actual plans in all the districts except in the Bolgatanga district. In the Bawku district the optimum plan generates 135 per cent more revenue while in the Sandama, Navrongo and Tumu they yield 38, 41 and 154 per cent more respectively than the actual plans in practice. In the Lawra and Wa districts the optimum plans are even more superior. They generate 460 and 2064 per cent more net revenue. These results indicate that the allocation of farmers' resources (except those in Bolgatanga district) is not consistent with profit maximization behaviour. Hypothsis Four (see chapter I) is therefore accepted. In the Bolgatanga district however, the plan actually adopted by farmers yield 3% more net revenue than the optimum plan.[1] The optimum plans confirm that the western sector of the Upper Region is a more prosperous agricultural area than the eastern sector. That the Bolgatanga and Navrongo districts are usually food deficit areas is also confirmed by the optimum plans and also by their comparison to the actual plans in practice (see Table 25). The table shows that the food deficit situations in the Sandama, Navrongo districts would improve substantially if optimum plan I for those districts are adopted. In the Bawku district adoption of the optimum plan would change the food deficit to a food surplus situation. On the other hand adoption of optimum plan by farmers in the Bolgatanga district will worsen the food situation in that district.

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[1] Note the entire Upper Region is a farming community where the degree of urbanization is very small.

Table 25

Comparison of Net Revenues from Actual Plans with Those from Optimum Profit Plans I

District	ACTUAL PLANS Without Autarky A	With Autarky B	Optimum Profit Plan I (with Autarky) C	C as % of B
Wa	¢1825.48	-¢ 141.46	¢2778.13	+ 2070
Lawra	¢3159.41	¢ 513.84	¢2878.89	+ 460
Tumu	¢2713.66	¢ 899.48	¢2325.12	+ 158
Sandama	¢ 497.09	-¢1505.54	-¢ 881.82	+ 41
Navrongo	¢1008.95	-¢ 678.82	-¢ 420.57	+ 38
Bolgatanga	¢ 753.10	-¢1755.68	-¢1799.66	- 3
Bawku	¢1286.48	-¢1026.77	¢ 365.10	+ 135

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[1] This result appears a little unusual.

The superiority of the optimum plans over the plans in practice may be better understood by examining the income penalties associated with the deviations from the optimum plans which make these plans more similar to the plans in practice. Income penalties (reduced costs) arise from any of the following departure from the optimum plan:

(i) forcing excluded activities into the optimum plan

(ii) changing the level of non-limiting resources (slack activities) and

(iii) changing the level of activities in the optimum plan.

In an attempt to raise at least some proportion of every kind of foodstuff used by the household, farmers end up diversifying more than their resource endowment economically permits. Understandably, diversification is a good strategy against risk and uncertainity. Nonetheless, in situations of resource scarcity it may have high opportunity cost because resources are shifted away from the right enterprises. This point may be illustrated with the opportunity costs (income penalties) associated with the optimum plan for the Sandama district. This plan yields 38 per cent more revenue than the actual plan in practice. Table 26 gives a summary of the opportunity costs (reduced cost column) associated with the plan. The most popular enterprise in the district is millet-sorghum-cowpea (mixed). It is however not included in the optimum plan and Table 26 indicates that forcing one acre of it into the optimum plan would result in a loss of ¢94.40 in net revenue. Similarly forcing one acre of cowpea or rice into the plan will lower the net revenue by ¢199.20 or ¢100.20

respectively. It can be shown from the table that diversification involving one acre each of cowpea (pure), millet-sorghum-cowpea (mixed) and rice (pure) has a total opportunity cost of ¢393.80. The optimum plan does not exhaust available family labour and working capital. Thus a forced utilization of ¢1.00 borrowed capital at the assumed interest rate diminishes the net revenue by ¢0.15. Similarly, the use of one man-day of hired labour leads to ¢4.00 of net revenue loss (see Table 26). Thus diversification which shifts scarce resources

Table 26

Opportunity Costs (Income Penalties) Associated with Optimum Profit Plan for Sandama

Activity	Level	Opportunity Costs (income penalty) per unit
M - S - Cow	0	¢ 94.40
Millet	0	¢ 50.80
Sorghum	0	¢ 80.70
Groundut	0	¢ 30.20
Rice	0	¢100.20
Cowpea	0	¢199.20
Borrowed Capital	0	¢ 0.15
Hired Labour	0	¢ 4.00
Land	10.30	¢280.20[1] (dual Activity)

[1] Shadow price of a unit of land resource.

away from the optimum enterprise is the primary cause of low net revenues obtained by many farmers in the region. This is further illustrated by the fact that in the Bolgatanga and Bawku districts the optimum enterprise selected by the programme are the most popular enterprises of the people. However, diversification does not allow the right dosage of investment for maximum profits. The same holds true for all the other districts.

Enterprise Specialization

The optimum plans suggest the need for enterprise specialization among the various districts of the region to ensure maximum net revenues for the farmers (see Table 24). Table 24 indicates that to obtain maximum profits farmers in the Navrongo and Tumu districts should specialize in the cultivation of groundnut (pure-crop). In other words,all the productive resources of the farmers should be invested in that enterprise. Their counterparts in the Sandama district should specialize in groundnut - bambara (mixed-crop) to realize optimum profits. Similarly farmers in the Bolgatanga and Bawku districts would have to invest all their productive resources in millet-sorghum-cowpea (mixed-crop) to optimize their net revenues. The enterprises selected for Wa and Lawra farmers are yams (pure-crop) and maize-sorghum-millet (mixed-crop). The districts would then trade their surplus output among themselves and export to other parts of the country.

Enterprise choice for the districts by the optimum plan is consistent with the theory of comparative advantage. Defined succintly, the theory suggests that individuals, regions or countries specialize in the production of the commodity/commodities which, with the given preferences, state of technology and resource endowments, they can produce at lower relative costs and to exchange their surpluses for the commodity/commodities they can produce only at higher relative costs.[1] Thus, for example, the Tumu and Navrongo districts have comparative advantage in producing groundnut over all the other districts. Similarly, farmers in the Bolgatanga and Bawku districts have comparative advantage in millet-sorghum-cowpea (mixed-crop) production. The benefits of specialization and trade along the lines of comparative advantage includes improved production efficiency.[2] But it is also suggested that specialization along the lines indicated would improve the efficiency of agricultural marketing throughout the region. This will result from a reduction in the problems of product assembly prior to distribution through the minimization of the scatter of farm units producing similar crops.

While the enterprise specialization as suggested by the optimum plans has considerable theoretical and intuitive appeal it does have some practical difficulties. Low income farmers are usually risk averse and use crop/enterprise diversification as a strategy against risks and uncertainity. For specialization to be attractive to the farmers the elements of risk and uncertainity in crop production would have to be eliminated or minimized. This could include the provision of irrigation water to supplement the inadequate and unreliable rainfall, a well established marketing and transportation systems with output price stabilization scheme, and disease and pest control knowledge and inputs. A crop insurance scheme to support an enterprise specialization policy might also be considered. The feasibility of the above suggestions are beyond the scope of this study.

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[1] For a good exposition of the theory of comparative advantage, see World Trade and Payments by Richard E. Caves and Ronald W. Jones. Boston, Toronto: Little, Brown and Company, 1973.

[2] For the benefits from trade based on comparative advantage, see Caves and Jones, ibid. and International Trade Policy, Agriculture and Development. Sorenson, U.L. East Lansing: Michigan State University Press, 1975.

Map 2 shows the areas of crop specialization as suggested by the optimum plans. The map shows that the western sector districts of Wa and Lawra will produce maize and yams. Groundnuts and bambara will be confined to the central parts of the region while cowpea will be cultivated only in the eastern sector. The two major staples of the region, millet and sorghum, will be confined to the western and eastern corners of the region.

Figure 4 shows the trading pattern that will result from the enterprise specialization suggested by the optimum plans for the seven districts. Navrongo, Sandama and Tumu districts will be suppliers of groundnuts to Wa, Lawra districts in the western sector and to Bolgatanga and Bawku districts in the east. Being next to the Bawku district, residents in the food deficient Bolgatanga district would obtain their supplies of millet and sorghum from the Bawku district (see Figure 4). In addition Bawku district would be the supplier of

Map 2

Upper Region, Enterprise/Crop Specialization by District
as Suggested by the Optimum Profit Plans

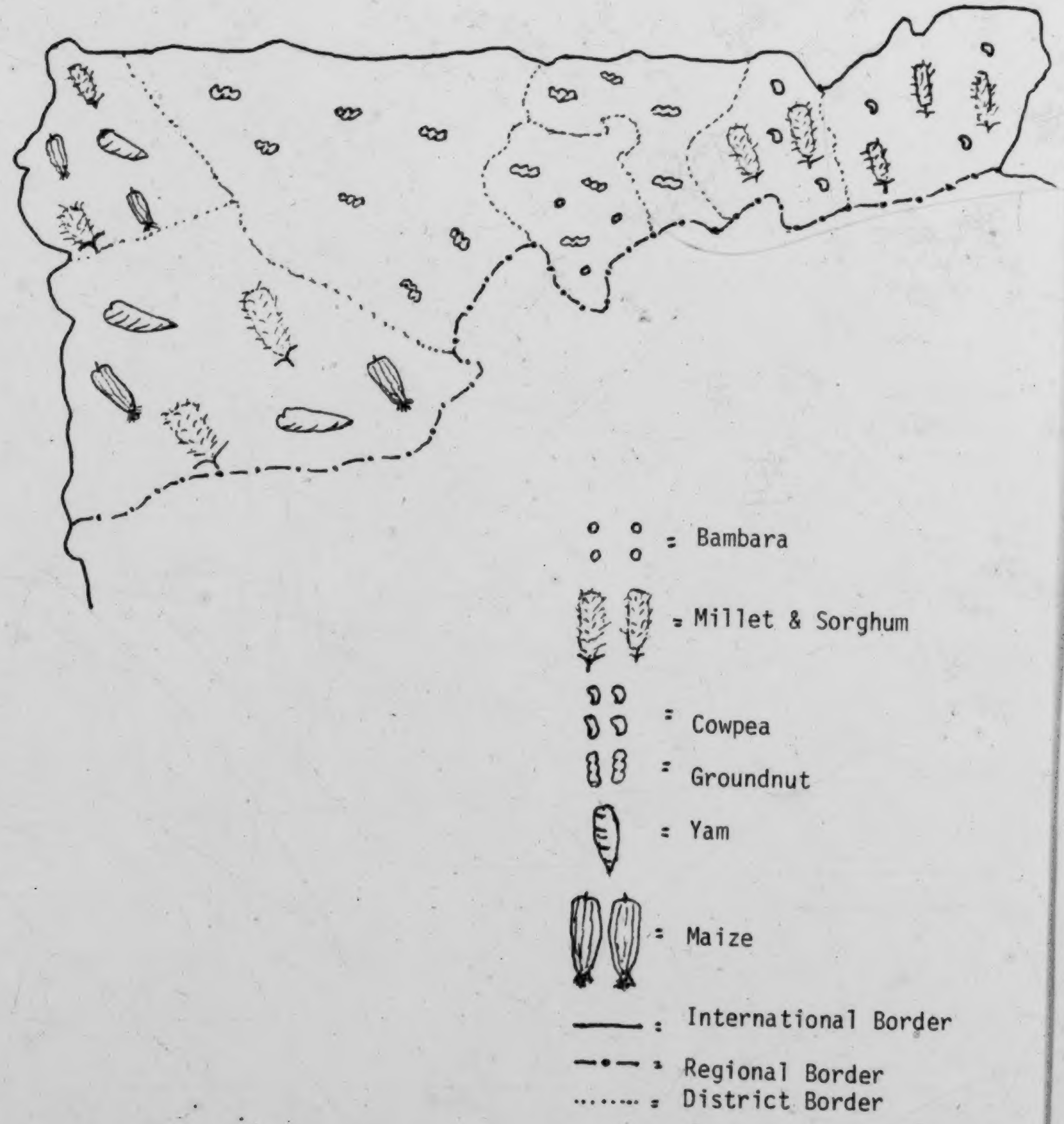
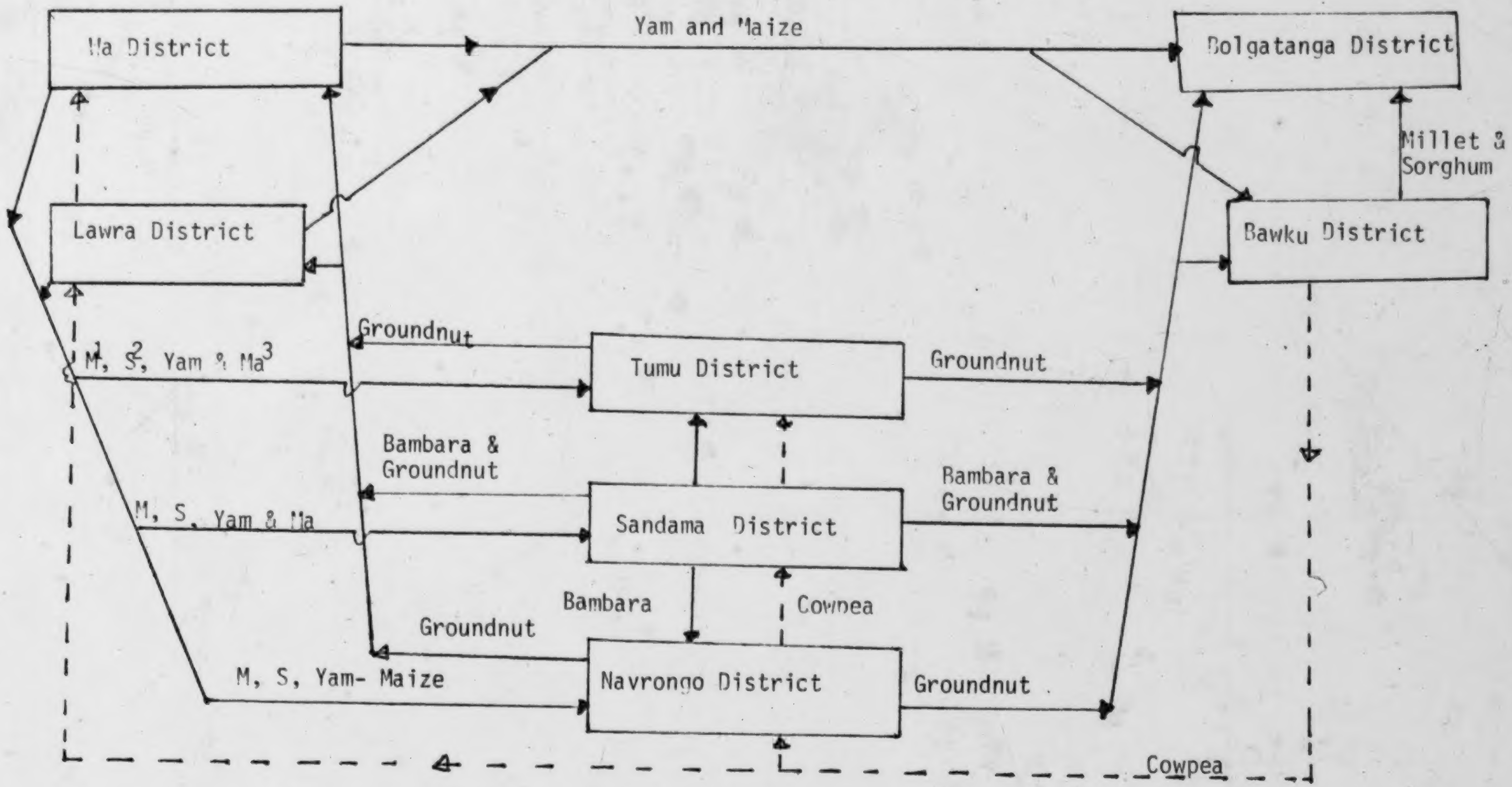


Figure 4
Commodity Trading Pattern Within The Upper Region Based On The Enterprise Specialization In The Optimum Profit Plans



[1] M = Millet [2] S = Sorghum [3] Ma = Maize

cowpea to all the other districts. The figure indicates that the flow of maize and yams would be from Lawra and Wa eastwards to the other districts. The Lawra and Wa districts would also be the major sources of millet and sorghum for neighbouring Tumu district and the Sandama district. It must be mentioned however, that relative transportation costs for commodities between the districts may alter the comparative advantage and the trading patterns suggested by the optimum plans.

Pure-crop Cowpea under Optimum Profit Plans

The results of the optimum plans confirm the assertion that cowpea cultivation (at least as a pure-crop) is relatively unprofitable. The plan indicates that for maximum profits, cowpea cultivation should be confined to Bolgatanga and Bawku districts. In these districts it should be cultivated as an intercrop with sorghum and millet. The relative profitability of pure-crop cowpea, under existing technology and prices, is low in all the districts of the region.

Attempts to force pure-crop cowpea into optimum plans involves large opportunity costs (income penalties). The post-optimality information of the plans reveal that substantial changes must occur in the unit costs (net return per acre) of pure-crop cowpea before the latter can become a feasible enterprise for entry into the optimum plans. Table 27 gives the opportunity costs of forcing one unit pure-crop cowpea in the optimum plans for the districts as well as the changes in the unit cost of this enterprise necessary to allow entry into the optimum plans. The table shows that forcing one acre pure-crop cowpea into the optimum plans for Wa and Lawra districts would reduce net revenues by ¢151.38 and ¢150.88 respectively. In the Bawku, Navrongo, Bolgatanga and Sandama districts the opportunity costs of forcing the cowpea activity into the optimum plans are ¢437.20, ¢246.60, ¢227.80 and ¢204.20 respectively. Table 27 also shows that for pure-crop cowpea activity to enter the optimum plan of the Wa district the gross margin (unit cost) of that activity must increase to ¢151.38 from ¢96.00. This can be achieved either through a yield increase of 185.0 lbs. (58%) all prices remaining unchanged or through the increase in the supply price of cowpea by ¢0.17 or 58 per cent (see Table 27). Similarly in the Bawku and Navrongo districts yield of pure-crop cowpea will have to increase by 327 and 251 per cent or

Table 27

Opportunity Cost to Optimum Profit Plans I of (Pure-Crop) Cowpea and Yield and Price Increases Implied by Unit Costs Changes of Cowpea

District	(Gross Margin) Reduced Costs and Unit Costs Changes ¢	Yield or Price Increases Implied by Unit Cost Changes[1] Yield (lb)	(%)	Price(¢)	(%)
Wa	151.38	185	(+ 58)	0.17	(+ 58)
Lawra	150.88	181	(+ 57)	0.17	(+ 57)
Tumu	175.00	375	(+150)	0.42	(+150)
Sandama	204.60	461	(+171)	0.48	(+171)
Navrongo	246.60	678	(+251)	0.65	(+251)
Bolgatanga	227.80	350	(+109)	0.37	(+109)
Bawku	437.20	1046	(+327)	1.05	(+328)

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[1] These are changes necessary to make (pure-crop) cowpea profitable or competitive enough to enter the optimum profit plans.

the supply price of the produce increased by the same percentages respectively before that activity enters the optimum plans of the two districts. The corresponding figures for other districts are given in Table 27.

Sensitivity Analysis and Shadow Prices

The dual solution to the primal LP problem gives the shadow prices or the marginal value products of the resources in the programme. The shadow price of a limiting resource is the additional return to be realized from making one additional unit of that resource available to the plan. Economic theory states that the producer maximizes his profit at the point where the marginal value product (MVP) of a resource equals its marginal cost. Under perfect competition, however, the marginal cost of a resource would equal its price. Thus it would be worth the farmer's while to commit more units of a resource into production so long as its MVP is greater than its price.[1]

Table 28 summarizes the shadow prices of the resources involved in the optimum plan for the Lawra district. To economize space the shadow prices in only this plan is discussed. Appendix Table 11 gives the shadow prices in the optimum plans for the other districts.

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[1] Indeed the theory of asset fixity indicates that an asset (resource) could be kept in production so long as the following relationship holds true:

Acquisition $P_x \geq MVP_x \geq$ Salavage Value_x , See Johnson, Glenn L. and C.L. Quance. Overpopulation Trap in the United States Agriculture. Baltimore: John Hopkins Press, 1971.

They have similar interpretation as those for the Lawra district. Both tables also provide the ranges within which the shadow prices are valid.

The shadow prices of family labour resource in the plan is zero. This is because there is excess supply of that resource than required to operate the plan. For example, 41.06, 252.24 and 91.76 man-days of March-April, May-June and July-August family labour are left unused in the plan (see column 4 of Table 28). The resource is unused because there are not enough of the other resources (land and capital) to be combined with to increase production. Accordingly the MVP or shadow price of family labour is zero indicating underemployment or open unemployment of available family labour.

The shadow prices of the operating capital (OPCAP) and borrowed capital (BORCAP) were ¢3.23 and ¢3.08 respectively. This shows that capital was a limiting factor to increased production and farm incomes in the Lawra district. An additional unit (¢1.00) of own-source working capital would yield ¢3.23 additional net revenue and an additional ¢1.00 of borrowed capital at the assumed interest rate would return ¢3.08. These shadow prices remain unchanged over wide ranges indicating that the optimum plan for the Lawra district is very stable. The shadow price of ¢3.23 for own-source working capital remains unchanged if working capital varies from ¢449.58 to ¢820.00. Similarly the shadow price of borrowed capital does not change if borrowed capital varies from ¢439.58 to ¢810.00.

The most limiting resource in the Lawra plan is land. It has a high shadow price of ¢233.96. This means that an additional acre

Table 28

Shadow Prices of Resources in Optimum Profit Plan I -- Lawra District

Resource	Total Supply Level	Used	Unused	Shadow Price ¢	Range of Resource Where Shadow Price is Valid Lower Bound	Upper Bound
Land	10.0 (acres)	10.0	0.0	233.96	7.65	10.45
M-AFL	262 (Man-days)	220.94	41.06	0.0		
M-JFL	262 (Man-days)	9.76	252.24	0.0		
J-AFL	262 (Man-days)	170.24	91.76	0.0		
PTOCTEL	262 (Man-days)	128.03	133.97	0.0		
N-DFL	262 (Man-days)	9.76	252.27	0.0		
OPCAP	¢510	510.00	0.0	3.23	449.58	820.00
BORCAP	¢500	500.00	0.0	3.08	439.58	810.00

of land resource would yield ¢233.96 additional net returns. This will remain unchanged if the supply of available land resource decreases to 7.65 acres. But will change if that resource increases by 0.45 acres.

It is obvious from the above and Appendix Table 11 that land is the single most limiting resource to increased agricultural production and farm incomes throughout the Upper Region. The severity of this limitation differs slightly from district to district. This is indicated by relative magnitudes of the shadow prices of this resource in the various plans. Generally, however, the results show that land shortage is more pronounced in the eastern sector of the region than in the western sector. The shadow prices of land in the plans for the Bolgatanga, Bawku and Navrongo districts were ¢336.00, ¢334.80 and ¢313.80 per acre respectively (see Appendix Table 11). Farmers in the western sector have larger land resource endowment and the shadow prices of this resource were therefore lower.

Working capital was found not to be a constraint in the eastern sector of the region. The shadow price of this resource was zero in all the optimum plans for the eastern sector. This means that the injection of capital in the form of cash loans to farmers in the Sandama, Navrongo, Bolgatanga and Bawku districts will by itself not increase agricultural production and farm incomes.[1]

Policy Simulation

The above analyses indicate that the potential for improved agricultural production and farm incomes exist in all the districts of the Upper Region. This potential can be realized if appropriate policy measures are undertaken to remove the constraints faced by the farmers. This will expand the production possibility frontiers open to the farmers and allow these frontiers to be fully exploited.

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[1] Heyer in a study of the Machakos in Kenya also found that the absence of credit was not a barrier to agricultural development -- see Heyer, J.Y. Agricultural Development and Peasant Farming in Kenya. Unpublished Ph.D. Thesis, London University, 1966, p. 81.

Three policy options are investigated here. They are (i) the possibility of putting more land under cultivation (ii) the provision of credit facilities in the form of cash loans and (iii) output pricing policy to generate increased output of a favoured crop (cowpea).

Putting More Land Under Cultivation

The low availability of the land resource was discovered to be the most critical constraint of farmers throughout the region - but more especially those in the eastern sector. Closely related to the 'quantity' of land resource supply is the quality of the supply and the system of land utilization -- the land rotation system of farming. The fertility of available land -- particularly in the Bolgatanga district and parts of the Navrongo and Bawku districts is poor. Land erosion is also common in these areas. The problem is further compounded by low and uncertain moisture conditions. Only the 'compound farms' out of the available supply of land are permanently cropped. The rest is cultivated under the land rotation system. This system requires that substantial portion of available land supply be allowed to fallow at any particular time to regenerate fertility.

The effects of easing the land constraint was investigated by allowing 50% of the available land resource to be put under cultivation. This is equivalent to a reduction of fallow lands in the districts where less than 50% of available land resource was utilized.

The districts involved were Wa, Sandama and Navrongo. The resulting optimum plans are presented in Table 29. The enterprise selection did not change in all cases, from that of Optimum Plan I.[1] In the Wa district the net profit increased from ¢2778.13 to ¢4605.26 in optimum Plan II when the land supply was increased from 9.3 to 18.6 acres. The enterprises selected were 12.4 acres of maize - sorghum - millet (mixed-crop) and 6.2 acres of yam (pure-crop). The Wa district thus becomes a substantial maize, sorghum and yam surplus area. Surpluses also occur for millet. Sandama and Navrongo become food surplus districts when the land resource is increased from 4.0 to 10.3 acres and from 4.0 to 6.0 acres respectively. Again the enterprise selection for these two districts are unchanged as in the optimum plan I. The net revenue for Sandama increased to ¢876.63 from a deficit of ¢881.83 while that of the Navrongo district increased to ¢213.00 from minus ¢432.57.

It is obvious from the above that farm incomes can be improved substantially by putting more of the available land resource under cultivation. This can be done merely by re-allocation of existing resources among the appropriate enterprises. Such resource reallocation can occur inspite of the existing land rotation. It must be mentioned, however, that the reduction of fallow land may entail losses in future output if the reduction is not accompanied by mea-

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[1] This also indicates that optimum Plans I were very stable.

Table 29

Optimum Profit Plans II (With 50% of Available Land Resource)

	Wa	Sandama	Navrongo
Land Used (Acres)	18.6	10.3	6.0
Allocation (Acres)	12.4 S-Ma-M 6.2 Yam	10.3 Gn-Bam	6.0 Gn
Crops Produced (lb)			
Millet	3348.85	-	-
Sorghum	3844.95	-	-
Cowpea	-	-	-
Groundnut	-	4326.0	3960.0
Bambara	-	1854.0	-
Yam	18590.55	-	-
Maize	3720.94	-	-
Rice	-	-	-
Crops Purchased (lb)			
Millet	-	2793.0	2769.0
Sorghum	-	1346.0	1385.0
Cowpea	340.0	340.0	260.0
Groundnut	570.00	-	440.0
Bambara	177.0	-	130.0
Yam	-	-	-
Maize	-	-	-
Rice	210.0	-	-
Crop Surpluses/Sold			
Millet	748.85	-	-
Sorghum	2544.98	-	-
Cowpea	-	-	-
Groundut	-	3746.0	3520.0
Bambara	-	1674.0	-
Yam	18240.55	-	-
Maize	3010.94	-	-
Total Net Revenue	¢4605.26	¢876.63	¢213.00

sures to augment soil fertility.

The compound farms are a partial solution to the land shortage problem of the Upper Region. They are consistent with Ester Boserup's thesis that population growth is a force which propels movement from a system of shifting or long-fallows towards that of permanent cultivation.[1] However, a more permanent solution would reside in the use of improved farming technology. This should include improved seeds, fertilizers, insecticides and irrigation if it would be inexpensive and have a high short-run payoff. These capital inputs would serve as substitute for land at least in the short run. The use of improved technology and better farm and soil management techniques are not simulated in the programme because of inadequate data on specific input-output coefficients. Nonetheless, it is believed that they will provide a more effective engine for increased agricultural production and farm incomes in the Upper Region than an increased supply of land resource per se.

Credit Policy

The provision of credit to the producer is one way of breaking out of the low income - low capital formation vicious circle which results in low productivity in traditional agriculture.[1] It must be noted, however, that the expansion of agricultural credit per se, as a source of capital does not always result in increased agricultural production. A necessary and sufficient condition for agricultural credit to be an accelerator of agricultural development is that it provides needed capital inputs into agriculture beyond those otherwise available to farmers from their own financial, physical and labour resources. Mosher has emphasized that farmers must spend the additional sum of money on improved seeds, fertilizers and implements to increase production.[2]

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[1] See Ester Boserup. The Conditions of Agricultural Growth - The Conditions of Agraian Change Under Population Pressure. Chicago: Aldine Publishing Company, 1965.

The shadow prices of working capital-OPCAP (and borrowing capital, BORCAP) in the optimum plans for Wa and Lawra districts indicate that further injection of this resource would generate increased incomes and agricultural production (see Table 28 and Appendix Table 11). This was further investigated by parametric variation of the amounts of borrowable capital at the assumed interest rate. Table 30 gives the net revenues associated with the various levels of borrowed capital. As well, the table provides the shadow prices associated with each level of borrowed capital. The shadow prices of land resource in the resulting optimum plans are given in the table.

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[1] Ragnar Nurkse described this vicious cycle of poverty when he said "There is small capacity to save resulting from a low level of real incomes. The low real income is a reflection of a low productivity, which in its turn is due largely to the lack of capital. The lack of capital is the result of the small capacity to save." See Ragnar Nurkse, Problems of Capital Formation in Under-developed Countries. New York: Oxford University Press, 1963, p. 5.

[2] See A.T. Mosher. Getting Agriculture Moving. New York: Frederick A. Praeger, October, 1965, p. 141.

Table 30

Effects of Increased Cash Credit on Net Revenues and Shadow Prices

	WA			LAWRA		
Borrowable Captial (BORCAP) ¢	Net Revenue ¢	Shadow Price of BORCAP ¢	Shadow Price of Land ¢	Net Revenue ¢	Shadow Price of BORCAP ¢	Shadow Price of Land ¢
440.00	4005.25	2.95	178.59	-	-	-
500.00	4759.83	2.57	196.48	2876.89	3.08	223.96
600.00	5017.19	2.57	196.48	3186.64	3.08	223.96
700.00	5274.55	2.57	196.48	3494.40	3.08	223.96
800.00	5531.91	2.57	196.48	3808.15	3.08	223.96
810.00	-	-	-	3832.93	0.00	640.20
1000.00	6046.64	2.57	196.48			
1500.00	7333.45	2.57	196.48			
2015.20	8659.38	0.00	536.20			

The table shows that an increase in the borrowed capital from ¢440 to ¢2015.20 in the Wa district all coefficients unchanged would cause 88% increase in the net revenue from ¢4605.26 to ¢8659.38. At

¢2015.20 the marginal value product of a unit (¢1.00) of borrowed capital is zero. This means ¢2015.20 is the limit of useful borrowed capital. Beyond that amount land becomes most limiting and further injection of cash credit yields no further revenue. The shadow price of land at this point is ¢536.00 up from ¢196.48 when the amount of borrowed capital was ¢1500. In the Lawra district, however, the limit of useful cash credits is only ¢810.00 and this increases the net returns from the optimum plan by 33.1 per cent from ¢2878.89 to ¢3832.93 (see Table 30). At that level of borrowed capital the shadow price of land is ¢640.20.

It must be emphasized that the limit of working capital prescribed by the optimum plans is dictated by the technology used. Clearly a higher amount of cash credit would be necessary under improved technology -- for the purchase of fertilizers, insecticides and improved seeds. This holds true for all the other districts of the region.

Output Pricing Policy

Output pricing policy can be a powerful tool for influencing the allocation of productive resources and the level and pattern of agricultural production. Furthermore, changes in relative supply prices of agricultural commodities influence, in the short-run, the relative and absolute income levels of producers. However, as indicated by Mellor agricultural price policy is an area of intense academic controversy because of the complicating short-run and long-run effects and because the long-run alternatives to price manipulation are often not understood.[1] The extent of the response by low income farmers to relative price changes has also been an area of controversy. Nonetheless, it was demonstrated in chapter IV that cowpea farmers respond positively to changes in relative prices both in the short and long run. This indicates that the supply prices of the crop can be manipulated to effect production changes.

It has been shown that considerable increases in the supply price of cowpea is needed, all coefficients and other prices remaining constant, to make pure-crop cowpea feasible enough for entry into the optimum plans (see Table 27). This is further investigated by parametric variation of the supply price of cowpea to observe the total output of cowpea vis-a-vis the output of the competing crops.

The industry's supply schedule is derived by the horizontal summation of the supply schedule of individual component firms.[2] Thus the district supply schedules for the various crops were obtained from horizontal aggregation[1] of the output from the optimum plans for the representative farms at the parametrized prices. The seven districts' supply schedules were further (horizontally) aggregated to obtain the supply schedules of the whole Upper Region. Table 31 gives the aggregate regional output of the various crops from the optimum plans at the parametrized cowpea prices. The table shows that no change occurs in the output or activity mix until the supply price of cowpea reaches ¢0.75 per lb. At that price, cowpea begins to replace millet, sorghum, groundnut and maize. A high sustitution of cowpea for groundnut and bambara occurs when the price of cowpea reaches ¢1.05 per lb. A pattern emerges at higher prices of cowpea with a more dramatic substitution rate of millet, sorghum, yams and maize for cowpea occurring at the price of ¢2.05 for cowpea (see Table 31).

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[1] See Mellor, J.W. Agricultural Price Policy and Income Distribution in Low Income Nation. World Bank, 1976, p. 1.

[2] $Qc = \sum_{i=1}^{n} Qc_i(Pc) = Qc \ (Pc)$.

Normative[2] Supply Response for Gowpea

The aggregate (regional) supply curve for cowpea is given by

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[1] Output of the optimum plans for the districts representative farms were multiplied by the corresponding number of holders in the districts to obtain the aggregate district output. The number of holders for the districts were as follows: Wa, 14057; Lawra, 12654; Tumu, 4830; Sandama, 9682; Navrongo, 17622; Bolgatanga, 30540 and Bawku, 27305. See Crop Production Statistics and 1978 Sampled Census of Agriculture. Ministry of Agriculture Economics and Planning Division, Accra, 1979, Table 40.

[2] Supply relations derived from **discontinuous or stepped production** functions under the profit maximization assumption are variously called in the literature e.g., normative, conditionally predictive and conditionally normative. In this study the terminology 'normative' is used for the sake of simplicity.

Table 31

Aggregate Regional Output of Crops from Optimum Plans At Various Cowpea Prices - (1000 tons)

Price/lb Cowpea	Cowpea	Millet	Sorghum	Groundnut	Bambara	Yam	Maize	Rice
0.30	19.1	99.7	59.0	68.3	8.0	244.8	27.5	0.0
0.45	19.1	99.7	59.0	68.3	8.0	244.8	27.5	0.0
0.60	19.1	99.7	59.0	68.3	8.0	244.8	27.5	0.0
0.75	19.1	99.7	59.0	68.3	8.0	244.8	27.5	0.0
0.80	55.3	113.8	66.0	37.1	8.0	246.9	23.3	0.0
0.90	55.3	113.8	66.0	37.1	8.0	246.9	23.3	0.0
1.00	55.3	113.8	66.0	37.1	8.0	246.9	23.3	0.0
1.05	72.2	113.8	66.0	0.0	0.0	246.9	23.3	0.0
1.15	75.2	113.8	66.0	0.0	0.0	246.9	23.3	0.0
1.25	75.2	113.8	66.0	0.0	0.0	246.9	23.3	0.0
1.50	75.2	113.8	66.0	0.0	0.0	246.9	23.3	0.0
1.60	75.2	113.8	66.0	0.0	0.0	246.9	23.3	0.0
1.75	75.2	113.8	66.0	0.0	0.0	246.9	23.3	0.0
1.85	75.2	113.8	66.0	0.0	0.0	246.9	23.3	0.0
2.00	75.2	113.8	66.0	0.0	0.0	246.9	23.3	0.0
2.05	107.0	57.5	23.4	0.0	0.0	62.2	0.0	0.0

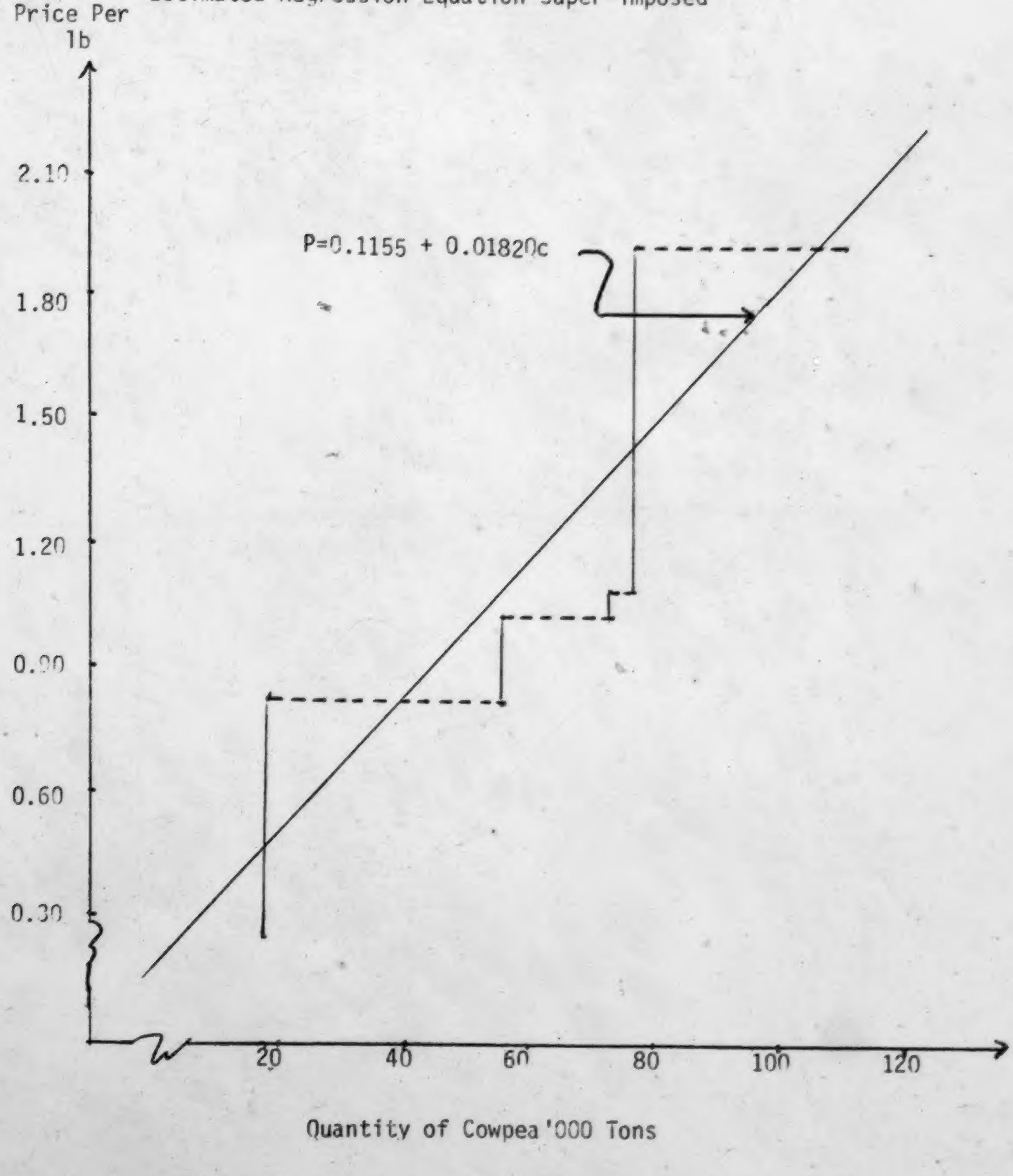
Figure 5. The figure is derived from the data presented in Table 31. The data in the table describes discrete points and therefore gives rise to a discontinuous schedule commonly known as 'stepped' supply schedule. The discontinuity of the schedule is due to the nature of LP as an analytical tool. The object of supply analysis in this section is to estimate the own price elasticity of supply of cowpea under the optimality conditions. In other words, an answer is sought to the following question. If farmers allocate their resources optimally (to maximize net revenues) what quantities of cowpea will be produced at various cowpea prices? An investigation is also made into the (product-product) relationships between the output of cowpea and that of the competing crops (millet, sorghum and groundnut) at those cowpea prices. To accomplish the above the following cowpea supply functions were estimated from the data generated in Table 31, using the ordinary least square technique:

1. $Qc = f(Pc)$
2. $Q_G = h(Pc)$
3. $Qc = g(Pc, Qm, Qs)$.

where Qc, Q_G, Qm and Qs are quantities of cowpea, groundnut, millet and sorghum respectively. Pc is the price of cowpea. The multiplicative functional forms of the equations provided the best estimates. The results are presented in Table 32. The table shows, as expected that the normative cowpea supply response is positive and significant at 0.005 level. The price elasticity of cowpea supply is 0.99 (Table 32). This confirms the results obtained in chapter IV. The cross-price elasticity of supply of groundnut with respect to cow-

Figure 5

Estimated Normative Supply Schedule With The Estimated Regression Equation Super-imposed



pea was found to be negative (-3.091) and highly significant (see Table 32). This indicates that output pricing policy in favour of cowpea will lead, in the long-run, to a decline in the output of groundnut since the two are competitive. On the other hand, the output elasticity of cowpea with respect to millet is highly positive (11.135) and significant at 0.005 level. This result is to be expected since the optimum plans suggest specialization of a mixed-crop enterprise of millet-cowpea-sorghum in the Bawku and Bolgatanga districts. Thus millet and cowpea are the joint products of the enterprise.

The reliability of supply estimates from normative models is an issue of current debate. Comparing positive estimates (from time series) with normative ones, Quance and Tweeten observed that the normative estimates have greater variability and are generally of larger magnitudes. They concluded that the LP derived "models are more realistic for showing regional shares of production (based on comparative advantage) than for showing the absolute level and elasticity of supply".[1] However, Shumway and Chang[2] in their work with LP

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[1] See Quance, C.L. and Tweeten, L.G. "Comparability of Positivistic and Normative Supply Elasticities for Agricultural Commodities", Policies, Planning and Management for Agricultural Development. Ed. IAAE, Oxford: Oxford Institute of Agrarian Affairs, 1971, pp. 451 - 58.

[2] See Schumway, C.R. and Chang, A.A."Linear Programming versus Positive Estimated Supply Functions: An Empirical and Methodological Critique" American Journal of Agricultural Economics, Vol. 59, No. 2, May, 1977, pp. 344 - 357.

Table 32

Results of Estimated Normative Cowpea Supply Response

	Estimated			Coefficients[a]		
Function	Intercept	Pc	Qm	Qs	R^2	F
Qc=f(Pc)	3.868	0.989*** (.145)	-	-	.7722	47.445[TT]
Q_G=h(Pc)	1.879	-3.091*** (.2837)	-	-	.7110	34.435[TT]
Qc=g(Pc, Qm, Qs)	-4.7589	0.229*** (.0842)	11.135*** (1.028)	-.381*** (.111)	.9796	192.14[TT]

a. Standard Errors are in parentheses

*** Coefficient significant at 0.005 level

TT F-Distribution at 1% significant level.

and Quadratic programming in California derived estimates somewhat contradictory to the findings of Quance and Tweeten. The supply estimates derived in this chapter compared with those derived in chapter IV seem to confirm Quance and Tweeten's observation that normative supply estimates yield larger elasticities than positive estimates. However, the results do not support their assertion that the normative estimates have greater variability. In fact the results obtained in this study point to the contrary. The standard errors of the normative estimates of price elasticity of cowpea supply derived in this study ranged from 0.084 to 0.284 while those of the positive estimates ranged from 0.3033 to 0.7636.

Summary and Conclusions

This chapter used the data generated in chapter III to design optimum profit plans for the representative farms in the seven districts of the Upper Region. The plans allowed for year-round staple food requirements for adequate nutrition. The linear programming technique was used. LP with parametrics was also used to simulate the following policy actions -- the provision of cash credit, output pricing policy and increase in supply of land resources (in some districts). A normative cowpea supply response was also estimated from the vectors of crop output generated from parametric pricing of cowpea.

The actual plans in practice departs significantly from the optimum profit plans and thus the farmers' decision behaviour is not consistent with profit maximization. However incomes will increase substantially if the optimum plans derived in this chapter are adapted. Inadequate supply of land resource is the most constraining to increased agricultural production and incomes throughout the region but land scarcity is particularly severe in the eastern sector. That is also the area (sector) where food is deficient and also where the injection of cash credit (under prevailing conditions) will not increase agricultural production and incomes. The optimum plans suggest enterprise/crop specialization among the various districts -- with Navrongo, Tumu specializing in (pure-crop) groundnut and Sandama district in groundnut -- Bambara (mixed-crop). Bawku and Bolgatanga districts should specialize in mixed-crop (early and late) millet-sorghum-cowpea. Farmers in Wa and Lawra districts should specialize in yam (pure-crop) and maize-millet-sorghum (mixed-crop). The results of the policy simulation indicate that an output pricing policy in favour of cowpea will generate increased cowpea production but that such a policy will cause a decline in groundnut and sorghum production but will benefit the production of millet. Finally it may be concluded from the analyses that a policy mix aimed at increasing agricultural output and incomes in the Upper Region should make available to farmers such capital inputs as improved seeds, insecticides, fertilizers, the cash credit to procure them and the knowledge to use them. These can be a substitute to increased supply of land resource. In the long run, however, the above should be combined with improved and reliable moisture facilities.

CHAPTER VII

OPTIMUM RESOURCE ALLOCATION UNDER RISK

One of the phenomenal difficulties of agricultural production in the Upper Region of Ghana is the variability of rainfall conditions. It is estimated that in every two out of ten years severe drought conditions occur to cause acute food shortages. Furthermore, in one out of every five years heavy torrential rains occur resulting in severe soil erosion and crop damages. This weather uncertainity clearly makes resource allocation decisions difficult for farmers. Consequently, any study of the farmers' decision-making process that fails to take account of weather is likely to produce unsatisfactory results.

This chapter therefore attempts to design efficient risk-minimization plans for farmers in the Upper Region. The chapter starts with a brief discussion of the theoretical model used and the assumptions. The results (plans) are then presented and compared with the profit-maximization plans developed in chapter IV and the plans observed in practice. The chapter ends with concluding remarks.

The Risk Programming Model

A number of recent studies have stressed the importance of risk in the decision making of peasant farmers.[1] The general consensus seems to indicate that the safety-first criterion tends to be followed whenever the satisfaction of the basic needs may be at risk.[2]

The model postulated in this study follows the portfolio selection model based on the expected-income (E) variance (V), criterion. This model assumes that farmers select from among alternative activities on the basis of their expected incomes and the associated income variances. This implies that the farmer possesses an expected income-variance (E-V) utility function. The model postulates further that the farmer is a risk averter i.e., the iso-utility curves are convex with the following relationships: $\partial E/\partial V > 0$ and $\partial E^2 / \partial V^2 > 0$. In other words, activities with higher V are preferred only if the associated E's are also greater and that the compensating E must be increasing at an increasing rate with any increases in V. This is a re-statement of the two hypotheses of the expected utility theory.[1] Markowitz[2] has demonstrated that a sufficient condition for the above to hold for a decision-maker is that the latter's Von Neuman and Morgestern (utility-of-income)[3] function is quadratic and convex downwards. More general conditions for the expected utility hypothesis to hold have been establed by Tobin but these conditions hold only when the expected incomes are normally distributed.[4]

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[1] See Wiens, T. "Peasant Risk Aversion and Allocative Behaviour: A Quadratic Programming Experiment." American Journal of Agricultural Economics, 58, 1976, pp. 629 - 35; Dillon, J. and J. Anderson. "Allocative Efficiency in Traditonal Agriculture and Risk." American Journal of Agricultural Economics, Vol. 53, 1971, pp. 26 - 32; Wolgin, J. "Resource Allocation and Risk: A Case Study of Smallholder Agriculture of Kenya." American Journal of Agricultural Economics, Vol. 57, 1975, pp. 622 - 30; Moscardi Edgardo and de Janvry Alain. "Attitudes Toward Risk Among Peasants: An Econometric Approach." American Journal of Agricultural Economics, Vol. 59, 1977, pp. 710 - 16.

[2] According to the safety-first rule, the motivating force of the producer in selecting from among available technological options is the security of generating large enough returns to cover his subsistence requirements. See Moscardi Edgardo and de Janvry Alain, op. cit.

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[1] The expected utility theory hypothesizes the following: (i) that given two prospects the one with the higher expected utility (E-U) will stand higher in the preference ordering of the individual in question, and (ii) that the higher probability of a preferred prospect is preferred to a lower probability. For detailed exposition of the expected utility theory see Green, John, H.A. Consumer Theory. (Revised Edition). London: MacMillan Press Ltd., 1976, pp. 213 - 231.

[2] See Markowitz, H. M. Portfolio Selection: Efficient Diversification of Investment. New York: John Wiley and Sons Inc., 1956.

[3] Von Neuman, J. and O. Morgenstern. Theory of Games and Economic Behaviour. Princeton: Princeton University Press, 1947.

[4] For these general conditions see Tobin, J. "Liquidity Preference as Behaviour Towards Risk." Review of Economic Studies. Vol. 25, February, 1958, pp. 65 - 86.

Relating the expected utility theory to the problem of farm enterprise selection, the expected utility from enterprise(s) can be shown to be a function of expected proceeds (expected gross margins) and the associated variances of the gross margins,[1] Where the utility of outcomes (from enterprises) is taken to be equivalent to the utility of gross margins. Thus if it is supposed that the gross margins forthcoming from enterprises are random variables with normal distribution, the expected utility maximizing farmer will choose from among alternative enterprises with the same risk (gross margin variances) the one(s) with the highest expected gross margins. Similarly, he will choose from among enterprises with the same expected gross margins the one(s) with the least risk. If the expected gross margin and the variance (riskiness) of the enterprises are expressed respectively as follows:

1. $E(Z) = \sum_{i=1}^{n} P_i(Z_i)$

2. $V = V(Z) = \sum_{i=1}^{n} \sigma_i^2 Z_i^2 + \sum_{i=1}^{n} \sum_{i=1}^{n} r_{ij}\sigma_i\sigma_j Z_i Z_j \quad i \neq j$

where,

P_i = expected gross margin per unit of Z_ith enterprises.

σ_i = the standard deviation of the gross margin per unit of

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[1] See Bauer, L. A Quadratic Programming: Algorithm for Deriving Efficient Farm Plans in A Risk Setting. Ph.D. Thesis. Oregon State University, 1971, pp. 27 - 28. (Unpublished).

Z_ith enterprise.

σ_i^2 = the variance of the gross margins per units of the ith enterprise.

r_{ij} = is the correlation coefficient between Z_i and Z_j enterprises.

From equaltions 1 and 2, the expected utility maximizing equation for the enterprises becomes

$$3. \quad \text{Max. } E(u) = \Sigma P_i(Z_i) - \frac{\lambda}{2}\left[\sum_{i=1}^{n} \sigma_i^2 Z_i^2 + \sum_{i=1}^{n} \sum_{i=1}^{n} r_{ij}\sigma_i\sigma_j Z_i Z_j\right]$$

which may be put in the following quadratic programming formulations to enable the selection of enterprise(s) based on the E-V criterion and subject to resource and other constraints expressed in the form of linear inequalities.

$$4. \quad \text{Max. } E(u) = Z^1P - \lambda/2 \; Z^1VZ$$

$$\text{subject to } QZ \leq A$$

$$Z \geq 0$$

where,

Z^1 = a column vector of activity/enterprise level (the decision variables).

P = a row vector of expected gross margin per unit of the activities.

V = n x n variance - covariance matrix of the gross margins of the activities (as from equation '2').

Q = m x n matrix of technical coefficients for activities and constraints.

A = m x 1 vector of farmers' total resource supply or other constraint levels.

λ = risk aversion parameter. It is a subjective measure of the farmer's aversion to risk. The larger its value the more conservative the farmer. It is the slope of the farmers (E-V) utility function.

The E-V model postulated above assumes that the farmer is a risk averter and selects his activities to maximize total expected gross margins while minimizing the associated risk all subject to his technological and resource constraints. Hazell has discussed the merits of the E-V model and observed that it is consistent with probability status regarding the likelihood of occurrence of different gross margin levels for a given farm plan.[1] Furthermore, the variance of expected gross margins from activities and between activities is completely specified by the coefficients of the variance-covariance matrix.

The difficulties of the model include the limited availability of computer codes for its estimation and the subjectivity of the measurement of the risk aversion parameter. Von Hohenbalken's Finite Algorithm for quadratic programming was used to solve the problem in this study.[2]

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[1] See Hazell, P.B.R. "A Linear Alternative to Quadratic and Semi-Variance Programming for Farm Planning Under Uncertainity." American Journal of Agricultural Economic, Vol. 53, February, 1971, pp. 53 - 62.

[2] For the theory behind Von Hohenbalken's Finite Algorithm for Quadratic Programming, see Von Hohenbalken, A Finite Algorithm to Maximize Certain Pseudo-concave Function on Polytopes Mathematical Programming 8. North-Holland Publishing Co., 1975, pp. 189 - 206.

That solution procedure was available in APL version and was therefore convenient to use. Following Wiens and Hazell the risk aversion parameter is estimated for each representative farm in the study by parametric variation from zero up to the value which allows full utilization of the available land resources.[1] Land is the most critical constraint (from chapter VI). This procedure ensures that the resource utilization in the optimum risk minimization plans are not substantially different from that in the plans in actual practice.

Data and Assumption of the Study

The major sources of risk confronting farmers in the Upper Region are (i) weather variation, principally rainfall variability and (ii) market risk from factor and product price variation. Rainfall variability affects yields and thereby causes variability in gross margins of cropping activities. Similarly, variations in factor or product prices result in variations in gross margins other things remaining constant. Nonetheless, time series data for farm gate prices (both factor and product prices) were unavailable for any of the districts. Consequently, risks from market sources are not considered in the study; i.e., constant prices are assumed in the estimation of the expected gross margins and the associated variances. The average farm gate prices for 1978 are used to derive the expected gross margins and variances. These prices are presented in Appendix Table 10.

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[1] Wiens, Thomas B. used this approach in examining the impact of yield uncertainity on peasant allocation among crops and the use of hired factor services in a Chinese village. See Wiens, Thomas B., op. cit. Also see Hazell, P.B.R., op. cit.

The exclusion of market risk is not expected to affect results of the analysis adversely. This is because, as Schuluter[1] and Wiens[2] observed, the variances of realized prices around expectation are frequently insignificant relative to the inter-temporal variance-covariance of yields and therefore price risk can frequently be disregarded in studies of the decision-making process involving peasant producers.

Time series yield data for the various activities for 1966-78 were obtained from the Ministry of Agriculture Offices in Accra and Bolgatanga. Since the technology of farming has remained virtually unchanged over the years, yearly variations in yields are attributed principally to weather variability. Thus, this study examines the impact of yield risk on the allocation of farmers' resources. Data of expected gross margins and the variance-covariance matrices for the representative farms are provided in Appendix Table 11 to16 . The matrices of the technical coefficients and the vectors and the resource constraint levels are the same as those used in the LP model in chapter V (see Tables 17 - 23).

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[1] See Schluter, M.G.G. "The Interaction of Credit and Uncertainity in Determining Resource Allocation and Incomes on Small Farms Surat District India." Employment and Income Distribution Project-Occasional Paper. No. 68. Department of Agricultural Economics, Cornell University, 1974.

[2] See Wiens, Thomas B., op. cit.

Optimum Risk-Minimization Plans

Table 33 summarizes the optimum risk-minimization plans for the representative farms of seven districts in the Upper Region. The plans call for great diversification of cropping activities and for small farm sizes. This is consistent with observed behaviour of farmers in the face of risk and uncertainity. The optimum plan for the Wa district involves the following: 0.241 acre sorghum-maize (intercrop), 6.274 (pure-crop) maize and 2.710 acres of millet-sorghum-cowpea-maize intercrop. The total revenue from the plan is ¢2244.55 and the risk aversion parameter involved in 0.5. Similarly, the optimum risk-minimization plan for farmers in the Lawra district comprises 0.199 acre pure-crop yam, 5.844 acre pure-crop maize and 3.957 acres millet-sorghum-cowpea (intercrop). The plan yields ¢2720.47 and the value of the risk aversion parameter involved is 0.25 (see Table 33). Total revenues from the plans for the Bolgatanga and Bawku districts are ¢435.90 and ¢1876.41 respectively and the plans involve 1.310 acres pure-crop millet and 0.710 acre millet-sorghum-cowpea (intercrop) for the Bolgatanga district and 5.796 acres of millet-sorghum-cowpea intercrop and 2.204 acres of millet-cowpea intercrop for the Bawku district. (see Table 33). In Navrongo, the plan calls for the allocation of all the available 4 acres of land resource to the groundnut-bambara intercrop activity. This generates ¢1158.24 total revenue. Only pure-crop activities occur in the optimum risk-minimization plan for the Sandama district. They comprise 0.979 acre millet, 0.444 acre rice and 2.577 acres cowpea and generate a total revenue of ¢487.55.

Table 33

Optimum Risk-Minimization Plans by District[1]

	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku
Allocation (Acres)	0.241 S-Ma	0.199 Yam	3.201 S-M-Cow	0.999 M	4.0 Gn-Bam	1.310 M	5.796 M-S-Cow
	6.274 Ma	5.844 Ma	1.161 M	0.444 Rice		0.710 M-S-Cow	2.204 M-Cow
	2.710 M-S-Cow-Ma	3.957 M-S-Cow	12.738 Cow	2.577 Cow			
Total Acres	9.225	10.0	17.1	4.0	4.0	2.02	8.0
Total Revenue	¢2244.55	2720.47	1900.72	487.05	1158.24	435.90	1876.41
Risk Aversion Parameter	0.50	0.25	0.125	0.50	0.50	0.50	0.25

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[1]
S = Sorghum (Guinea Corn)
M = Millet
Ma = Maize
Cow = Cowpea
Bam = Bambara Beans
Gn = Groundnut

Risk Minimization Plans Vs. Profit Maximization Plans and Plans in Actual Practice

The type and levels of activities comprising the efficient risk-minimization plans differ substantially from those appearing in the profit maximization plans. The former plans show considerable diversification and comprise generally smaller farms. They are indeed closer to the farm plans observed in actual practice. The optimum profit plans showed much specialization (see Table 24, and Map 2).

Table 34 provides a comparison of the total revenues derived from the optimum profit-maximization, the optimum risk-minimization and actual plans observed in practice. The table shows that the profit maximization plans (quite expectedly) yielded higher revenues in all the districts than both the plan in actual practice and optimum risk-minimization plans.

Compared with the plans in actual practice, the risk-minimization plans yielded mixed results. For example, in the Wa, Navrongo and Bawku districts they produced 23%, 15% and 46% more total revenues respectively than the plans in actual practice (see Table 34). In the remaining districts however, the risk plans were more conservative - yielding lesser total revenues than the actual plans. Generally, however, the revenues from the risk plans were closer to those generated by the actual plans in practice. The implication of this is that the farmers' decision-making behaviour is closer to risk minimization than profit maximization behaviour. This situation is particularly more evident in the Sandama, Wa, Lawra, Navrongo and Bolgatanga districts than in the Tumu and Bawku districts as indicated by the closeness of the revenues from the two plans (see Table 34).

Table 34

COMPARISON OF TOTAL REVENUES FROM OPTIMUM RISK MINIMIZATION AND PROFIT MAXIMIZATION PLANS AND FROM PLANS IN ACTUAL PRACTICE

	(A) Plans in Actual Practice ¢	(B) Profit Maximization Plans ¢	(C) Risk Minimization Plans ¢	B as % of A	C as % of A
Wa	1825.48	4745.07	2244.55	+160	+ 23
Lawra	3159.41	5524.46	2720.47	+ 75	- 14
Tumu	2713.66	4138.90	1900.72	+ 53	- 30
Sandama	497.09	1120.80	487.05	+125	- 2
Navrongo	1008.95	1267.20	1158.24	+ 26	+ 15
Bolgatanga	753.10	709.12	435.90	- 6	- 42
Bawku	1286.48	2678.35	1876.41	+108	+ 46

Cowpea Production in the Optimum Risk-Minimization Plans

The status of cowpea changes dramatically from one of a subsidiary crop in the profit-maximization plans in chapter V to that of a dominant crop in the optimum risk minimization plans. It was demonstrated in chapter V that considerable improvements (58 - 327%) in yields and/or output prices have to occur before cowpea appears in the optimum profit plans (see Table 27). However, inspite of the relative unprofitability of the crop the relative yield stability makes that activity feature prominently in the optimum risk-minimization plans for Tumu and Sandama districts as pure crop and in the Wa, Lawra, Bolgatanga and Bawku districts as an intercrop (see Table 33). The risk plans for Tumu and Sandama include 12.738 and 2.577 acres respectively of pure-crop cowpea. These results contradict Hypothesis six of the study. Thus the null hypothesis, that under risk minimization conditions cowpea cultivation is consistent with optimum resource allocation is accepted. The results show that cowpea cultivation should be popular with risk-averse farmers. The implication of this finding is that yield variability of cowpea is low and that the potential exists for increased cultivation of the crop even under prevailing farming conditions and technology both as a pure-crop and as an intercrop.

Concluding Remarks

In this chapter quadratic programming procedure was used to design optimum risk-minimization farm plans for the representative farms of the seven districts in the Upper Region. These plans were then compared with those in actual practice and with the optimum profit plans devised in chapter V. The results show that the risk minimization model is fairly consistent with the decision-making behaviour of the farmers studied. The optimum risk minimization plans call for substantial diversification of activities in proportion close to those observed in practice. They also involve small farm sizes which is also consistent with plans in actual practice. The degree of risk aversion varies among the seven districts. This is evidenced by (i) the relative values of the risk aversion parameter and (ii) by the differences in the revenues from the risk minimization plans compared with those derived from the plans in actual practice. Cowpea features prominently in the risk minimization plans and this contradicts the hypothesis that cowpea cultivation is inconsistent with optimum resource allocation under risk minimization conditions. Finally, it may be concluded that because risk, from rainfall variability plays a considerable role in determining the resource allocation in the Upper Region, policy measures that will reduce yield variability may serve as an important engine for increasing agricultural production in the region.

CHAPTER VIII

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary and Conclusions

The agricultural sector of the Ghanaian economy has had a checkered history and requires sound policy measures to promote sustained growth in production, productivity and farm incomes. Recent efforts have been fashioned on regional and commodity approaches to agricultural development. In the Upper Region, this is evidenced by the cowpea project and the establishment of Upper Regional Agricultural Development Project to administer agricultural development efforts in the region and to promote increased production of some specific crops including groundnut, millet, sorghum in addition to cowpea. To succeed in their objectives these projects should administer policy actions which are premised upon sound economic analysis and facts about the agricultural production in the region. This study has attempted to provide such analysis and facts.

More specific objectives of the study were included in the following:

(i) investigation of the conditions of crop production in the Upper Region to determine the policy set necessary to promote increased agricultural output and incomes;

(ii) estimation of cowpea supply resource;

(iii) designing optimum profit strategies for farmers in the region under prevailing conditions and under various simulated policy situations;

(iv) determination of the trade-off between increased cowpea output and output of groundnut, millet and sorghum under the above strategies; and

(v) designing optimum risk minimization strategies for the farmers.

To accomplish the above objectives, the following analytical tools were used: multiple regression analysis, linear programming technique with parametrics and quadratic programming. The Nerlovian Adjustment Lag model was postulated in the regression analysis to estimate cowpea supply function. Cowpea acreage was used as proxy for the quantity produced and the multiplicative version of the function fitted using the Instrumental Variable procedure.

The Upper Region was divided into seven districts according to differences in resource endowment and a representative farm constructed for each district for the purposes of designing the optimum profit plans. LP was used to derive the initial plans and LP with parametrics used to simulate changes in credit, land and output pricing policies. A normative cowpea supply schedule was estimated from the vector of cowpea outputs generated from the parametric variation of cowpea prices using Ordinary Least Squares. Finally, seven optimum risk minimization plans were designed, one for each of the seven districts. The E-V (expected income-variance) model was postulated and the resultant quadratic programming problem solved with the aid of Von Hohenbalken's Finite Algorithm for ~~quadratic~~ programming.

The time-series acreage and price data used in the supply analysis were obtained from Annual Reports of the Ministry of Agriculture in Accra and Bolgatanga. The time-series rainfall data were taken from the reports of the Meteorological Services Department in Accra and Bolgatanga. Similarly, the annual reports of the Ministry of Agriculture were the sources of the time-series yield data used in the quadratic programming analysis. A sample survey of farm holders was conducted between September 1978 and February 1979 to collect primary data on farmers' resource supply levels, production activities and input-output coefficients. 350 farm holders were studied throughout the region. Data obtained from the survey were used in the LP analysis.

The signs of the estimated coefficients of the cowpea supply function conformed to a priori economic theory. The short-run and long-run own-price elasticities were estimated to be 0.078 and 2.26 respectively and were significant at 0.05 level. The elasticity of cowpea supply (acreage) with respect to rainfall (up to the planting time) was -1.5872 and significant to 0.025 level. This indicates that high rainfall induces farmers to shift land resources away from cowpea to perhaps the more favoured crops - millet and sorghum. Thus Hypothesis One of the study, that the acreage planted to cowpea is directly correlated to the price of cowpea in the previous year and Hypothesis Three, that farmers adjust their cowpea acreage according to rainfall variability, were accepted.

The cross-price elasticity of supply of cowpea with respect to millet was negative but statistically insignificant. The exogenous variables postulated in the study explained only 57 per cent of the variation in cowpea supply indicating that the model excluded other important variables in the cowpea supply function.

The optimum profit plans were designed allowing for on-farm-production of the annual food requirements for adequate nutrition. The plans were based on prevailing farming technology. As expected, the optimum profit plans generated substantially more revenues than the plans in actual practice in all the districts. The Bolgatanga district was the only exception. In the latter case, the plan in practice was superior. The optimum profit plans called for considerable enterprise/crop specialization and inter-district commodity trading. They indicated that farmers in Sandama district should invest in the groundnut-bambara intercrop enterprise while their counterparts in Navrongo and Bawku districts should invest all their resources in millet-cowpea-sorghum intercrop enterprise only. Yam (pure-crop) and maize-sorghum-millet (inter-crop) were the two optimum profit enterprises for farmers in the Wa and Lawra districts. Results of the optimum profit plans led to the acceptance of hypothesis four of the study, that farmers'resource allocation is not consistent with profit maximization behaviour, i.e., excluding uncertainty aspects.

The results showed that land is the most critical constraint to increased agricultural production and incomes in Upper Region under existing farming technology. Land resource constraint takes the form of both 'quantity' and quality of supply. The land constraint had the highest shadow prices in all the districts and augmenting that resource would generate increased output and incomes. It is submitted, nonetheless, that improved technology in the form of improved seeds, fertilizers and improved soil and farm management practices should serve as substitute for additional land resource in the short-run.

Results from the simulation of credit policy indicated that injection of cash credit under prevailing production technology would generate increased incomes and agricultural output in the Wa and Lawra district only. The limits of useful cash credit per farm in the Wa and Lawra districts were found to be around ¢2015.00 and ¢810.00 respectively. In all the other districts working capital was not a constraint to increased production and incomes. Hence, in these areas further injection of cash credit would not generate any further incomes and agricultural production under prevailing agricultural technology.

The results of the optimum profit painted an unfavourable picture for cowpea. Cowpea appeared in the optimum profits plans only as a subsidiary crop. The results indicated that its cultivation should be confined to the Bolgatanga and Bawku districts only. They also confirmed the assertion that pure-crop cowpea is relatively an unprofitable enterprise. Substantial improvements in yields and or prices have to occur all other things remaining unchanged, before pure-crop cowpea becomes profitable enough to enter the optimum profit plans. In the Wa and Lawra, for example, yields or output prices would need to increase by 57 and 58 percent respectively before pure-crop cowpea entered the optimum profit plans. Similarly in the Tumu, Sandama, Navrongo, Bolgatanga and Bawku districts yield increases must be around 150, 171, 251 and 328 percent of existing levels respectively before the enterprise enters the optimum profit plans.

Output pricing policy favouring cowpea, all other things remaining unchanged, generated increased cowpea output. Such a policy also benefits the output of millet but led to a drastic decline in the outputs of groundnut and sorghum. In other words, millet and cowpea are complementary enterprises while cowpea is competitive to groundnut and sorghum (at high cowpea prices). These results led to the acceptance of the Hypothesis that the acreage planted to cowpea is inversely related to the prices of groundnut and sorghum but directly related to the price of millet.

The optimum risk-minimization plans involved small farm sizes and called for substantial diversification of activities in proportions close to those observed in actual practice. The returns from the plans were lower than those from the optimum profit plans. But the results showed that the risk minimization model is consistent with the decision-making behaviour of farmers in the Upper Region. Cowpea featured prominently in the optimum risk minimization plans. This enabled the acceptance of the null of Hypothesis Six, i.e., that cowpea cultivation is consistent with optimum resource allocation under risk minimization conditions. The results of the risk minimization plans led also to the acceptance of hypothesis five of the study, that farmers allocate their resources to minimize yield of income variance.

The results showed ~~that~~ great potentials exist in all the districts of the Upper Region for increasing agricultural output and incomes even under prevailing farming conditions and technology. These potentials are, however, greater in the western sector than the eastern sector of the region. The potentials are currently not being realized principally because of yield risks and uncertainity facing the farmers.

Policy Recommendations from the Study

The results of the study have far-reaching implications for policy to promote agricultural development in general and increased cowpea output in the Upper Region. The results indicate that the potential for increased farm output and incomes exist if farmers would shift away from self-sufficiency to market oriented, profit-maximizing production. Because farmers' decision-making behaviour is also consistent with risk minimization, powerful policies will be required if (i) farmers are to adopt the optimum profit maximization plans, (ii) over-all agricultural productivity in the region is to be improved to its full potential and sustained and (iii) cowpea output is to be increased substantially without sacrificing increased output of such crops as groundnut, millet and sorghum.

Such policy measures should include programmes to reduce yield risk and uncertainity. This suggests efforts to provide irrigation or moisture conservation facilities to ensure yearly availability of moisture for crop and livestock production. The feasibility of establishing a farm food security or crop insurance scheme may also be considered. Such a scheme may be more cost effective than irrigation and may provide an immediate incentive to farmers to adopt the optimum profit maximization plans. Policies to promote yield stability should introduce new crop varieties which are drought resistent and higher yielding. Pest control measures to minimize yearly crop damage may also be considered.

A renewed extension drive may be necessary to educate farmers to use the above facilities and to promote more market oriented production, i.e., reduce cultivating more crops for the sake of self sufficiency and shift towards cash crop production. This drive would entail improvement in existing ratio of extension worker to farmers, improvement in the mobility of the extension worker and equipment of the same with information and inputs which will convinced farmers to change. The formation of consumer cooperative at the village level or farm supply markets to handle the stocking and distribution of staple foods and to promote purchased inputs may also be considered. The local staple foods cooperatives will promote the drive towards enterprise specialization.

The success of the enterprise specialization will also depend upon the extent to which the marketing system is made responsive enough to be able to handle efficiently a larger flow of commodities between the districts within the region. This will require a marketing policy which will provide reliable transportation (network of roads with a complement of vehicles) and storage facilities. These facilities must be supplemented by sufficient cash funds for the purchase of the produce from the farmers. The prices paid to the farmers should be remunerative enough to serve as incentives for sustained output increases.

Land was found to be the most constraining resource to increased agricultural output and incomes. The land constraint, however, has many facets. Apart from low physical supply, there are the problems of low soil fertility and excessive fragmentation of the available land. Excessive fragmentation is a direct result of population growth and the system of inheritance or land tenure. It will therefore require a radical political policy to correct. Meanwhile, a new farm organization may be promoted by encouraging farmers to form cooperatives to operate larger farm units in order to effectively take advantage of improved technology and economies of scale. Farmers must also be encouraged, through extension efforts, to use improved farming technology,i.e., fertilizers, improved seeds and crop varieties and some of the approved crop rotations. This will help to cut down the land fallow periods and thereby encourage a more intensive use of available supply of the land resource. Provision of cash credit to farmers in Wa and Lawra districts will help to raise their output and incomes substantially.

A special effort will be required to promote increased cowpea output without sacrificing increased output of groundnut, millet and sorghum. Such effort must endeavour to raise the relative profitability of cowpea cultivation through the introduction of new pest and drought resistent and high yielding varieties. Cowpea farmers must be encouraged to use fertilizers and pesticides through subsidy and credit programmes supported by easy access to extension assistance.

Such efforts must also be supplemented by a marketing system which will purchase cowpea from the farmers at harvest time to prevent post-harvest losses due to weevil and other sources. These efforts must aim at raising cowpea yields from 57 to 328 percent of existing levels (depending upon the district). These efforts to increase the supply of cowpea should be complemented simultaneously by efforts to raise the level of cowpea demand throughout the country. This will make the farm gate price of cowpea remunerative enough to generate sustained output increases without much cost to government.

Limitations of the Study and Recommendations for Future Studies

The study has provided only a partial analysis of the agricultural industry of the Upper Region. This is because livestock production, a very imporant sector of the industry, was left virtually untouched. Since the region produces the largest proportion of the country's livestock, future studies would do well to investigate the livestock sector with the view to exploring the linkages between that sector and crop production. The linkages, are, nonetheless considered weak and less consequential.

The design of the optimum farm plans was based on existing technology. Improved technology was not incorporated because of the lack of specific data on input-output coefficients for the region. This has precluded any effective comments on the effects of introducing specific technological changes on farmers' production decisions. Since efforts at agricultural development in the region can not succeed without technological change vigorous agronomic and economic research should be pursued to provide basic input-output data on approved technologies and practices. These data can then be used in future economic analyses to guide policy.

Agronomic research must be carried out to ascertain fertilizer mix required to increase yields of the various crops in the respective soil situations in the region. Research must also be carried out to evolve high yielding drought resistent crop varieties for introduction to farmers in the region. Similarly research must be conducted to evolve viable crop rotations which can be adopted in order to reduce the length of land fallow periods and obtain high crop yields.

Finally in the present era of energy shortage the planning of agricultural development must incorporate energy requirements and the strategies for meeting energy needs. Future work must endeavour to research energy needs and concerns.

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APPENDIX

Appendix Table 1*

Consumer Price Index and Index Numbers of Real GNP and Per Capita Income 1960 = 100

Year	Consumer Price Index	Index Number of Real Per Capita Income	Index Number of Real GNP
1961	106	100.7	103.2
1962	116	102.8	108.7
1963	121	102.8	111.6
1964	135	102.8	114.7
1965	170	100.7	115.5
1966	178	97.8	116.2
1967	168	97.1	118.0
1968	185	95.0	118.4
1969	219	95.7	127.8
1970	228	105.0	137.9
1971	249	113.5	138.5
1972	273	110.6	132.5
1973	322	117.0	130.7
1974	380	122.7	137.3

*SOURCE: Economic Survey (Various Years), Central Bureau of Statistics, Accra.

Appendix Table 2*

Industrial Origin of Gross Domestic Product (1955/57 - 1975)

	1955/57		1960		1968		1975	
	Value Million ¢	(% of GNP)	Value Million ¢	(% of GNP)	Value Million ¢	(% of GNP)	Value Million ¢	(% of DNP)
Total Agricultural Production	385.8	(51.2)	490.0	(51.8)	785.5	(38.6)	968.8	(35.0)
Cocoa	99.0	(13.1)	151.4	(16.0)	173.0	(8.5)	249.1	(9.0)
Forestry	37.0	(4.9)	52.0	(5.5)	79.4	(3.5)	99.6	(3.6)
Food Production and other agricultural Products	249.8	(33.2)	286.6	(30.3)	533.2	(26.2)	620.0	(22.4)
Mining	37.0	(4.9)	42.6	(4.5)	44.8	(2.2)	55.4	(2.0)
Manufacturing	8.8	(1.2)	18.0	(1.9)	154.7	(7.6)	240.8	(8.7)
Construction	321.9	(42.7)	35.9	(3.8)	73.3	(3.6)	105.2	(3.8)
Oil and Fuel			-	-	46.8	(2.3)	110.7	(4.0)
Transport and Services			359.5	(38.0)	930.00	(45.7)	1204.1	(43.5)

*SOURCES: Kodwo Ewusi. West African Economies - Some Basic Economic Problems. Technical Publication Series No. 25, Institute of Statistical Social and Economic Research Legon University of Ghana, 1971, p. 54 and Birmingham, et al., *op. cit.*, p. 56.

Appendix Table 3*

Holders' Educational Background and Non-Farm Employment

District	Number of Holders	(% of Sample)	Average Income From Non-Farm Employment/ Holder	Illiterates Holders	(% of Sample)	Holders With Primary Education	(% of Sample)	Holders With Above Primary Education	(% of Sample)
Wa	2	(4)	¢ 40	49	(98)	-		1	(2)
Lawra	8	(16)	¢377	47	(94)	2	(4)	1	(2)
Tumu	0	(-)	-	20	(100)	-		-	(-)
Sandama	1	(5)	¢ 72	17	(85)	-		3	(15)
Navrongo	1	(2)	¢ 38	48	(96)	-		2	(4)
Bolgatanga	34	(49)	¢685	68	(97)	1	(1)	1	(1)
Bawku	4	(4)	¢ 36	90	(100)	-		-	(-)
Total Samnle	50	(14)	¢215	339	(97)	3	(.01)	8	(2)

*SOURCE: Compiled from Survey Data.

Appendix Table 4*

Distribution of Holders by Age

Age	Wa		Lawra		Tumu		Sandama		Navrongo		Bolgatanga		Bawku		Total Region		
	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	#	(%)	Cumulative %
15 - 24	3	(6.1)	1	(2)	0	(0)	0	(0)	2	(4)	3	(4.3)	0	(0)	9	(2.6)	100
25 - 34	8	(16.3)	5	(10)	1	(5)	5	(26.3)	5	(10)	5	(7.1)	7	(7.8)	36	(10.3)	97.4
35 - 44	16	(32.7)	6	(12)	11	(55)	5	(26.3)	23	(46)	31	(44.3)	28	(31.1)	120	(34.5)	87.1
45 - 54	9	(18.4)	16	(32)	6	(30)	6	(31.6)	13	(26)	21	(30.0)	33	(36.7)	164	(29.9)	52.6
55 - 64	8	(16.3)	17	(34)	0	(0)	2	(10.5)	7	(14)	7	(10.0)	12	(13.3)	53	(15.2)	22.7
65 and Over	5	(10.2)	5	(10)	2	(10)	1	(5.6)	0	(0)	3	(4.3)	10	(11.1)	26	(7.5)	7.5
Total Sample	46	(100)	52	(100)	48	(100)	44	(100)	45	(100)	46	(100)	49	(100)	44	(100)	-

*SOURCE: Compiled from Survey Data.

Appendix Table 5*

Percentage Distribution of Holders By Complaints/Problems with Land Resources

Problems District	Low Soil Fertility	Long Distance From Homesteads	Tenancy Problems	Low Rainfall
Wa	67	10	-	57
Lawra	42	10	18	68
Tumu	95	-	-	55
Sandama	80	-	5	100
Navrongo	82	-	-	100
Bolgatanga	77	1	1	94
Bawku	69	8	0	67
Total Region	70	5	3	77

*SOURCE: Compiled from Survey Data.

Appendix Table 6*

Average Herd Sizes and Average Value of Livestock Per Holder by District

	Cattle	Sheep	Goats	Poultry	Pigs	Total Average Value ¢	Average Value of Sales/Use Per Year ¢
Wa	3.3	2.6	3.6	12.3	0.4	2172	398
Lawra	5.0	5.8	5.6	17.9	1.8	3493	347
Tumu	3.4	3.2	2.8	7.5	0.2	2474	292
Sandama	4.1	7.1	3.0	37.6	-	5465	833
Navrongo	1.8	3.2	3.1	20.0	-	2162	220
Bolgatanga	2.3	2.7	3.8	28.0	0.7	3143	997
Bawku	2.4	2.9	3.0	11.8	0.6	1953	740
Total Region	3.0	3.5	3.6	19.8	0.6	2687	668

*SOURCE: Compiled from Survey Data.

Appendix Table 7*

Distribution of Holders by Value of Livestock and Poultry Possessed

Value Per Farmer ¢	Wa #	Wa (%)	Lawra #	Lawra (%)	Tumu #	Tumu (%)	Sandama #	Sandama (%)	Navrongo #	Navrongo (%)	Bolgatanga #	Bolgatanga (%)	Bawku #	Bawku (%)	Total Region #	Total Region (%)
Over 5000	9	(20)	11	(24)	4	(21)	6	(32)	6	(12)	15	(21)	3	(3)	54	(16)
4501 - 5000	-		1	(2)	-		1	(5)	3	(6)	3	(4)	-		8	(2)
4001 - 4500	-		-		1	(5)	-		2	(4)	3	(4)	3	(3)	9	(3)
3501 - 4000	-		-		1	(5)	-		3	(6)	1	(1)	1	(1)	6	(2)
3001 - 3500	1	(2)	1	(2)	-		-		1	(2)	3	(4)	2	(2)	8	(2)
2501 - 3000	2	(5)	1	(2)	-		1	(5)	2	(4)	1	(1)	1	(1)	8	(2)
2001 - 2500	-		5	(11)	-		1	(5)	2	(4)	3	(4)	6	(7)	17	(5)
1501 - 2000	2	(5)	4	(9)	2	(11)	3	(16)	1	(2)	3	(4)	7	(8)	22	(7)
1001 - 1500	4	(9)	10	(22)	3	(16)	1	(5)	3	(6)	2	(3)	8	(9)	31	(9)
501 - 1000	8	(18)	8	(17)	3	(16)	2	(11)	14	(28)	16	(23)	9	(10)	60	(18)
0 - 500	18	(41)	5	(11)	5	(26)	4	(21)	13	(26)	20	(29)	50	(58)	115	(34)
Total	44	(100)	46	(100)	19	(100)	19	(100)	50	(100)	70	(100)	90	(100)	338	(100)

*SOURCE: Compiled from Survey Data.

APPENDIX TABLE 8:1 - 8:11

CROP BUDGETS -

AVERAGE LABOUR AND OTHER INPUT REQUIREMENTS, PRODUCTION COSTS, AND RETURNS PER ACRE AND PER MAN-DAY OF LABOUR

Appendix Table 8.1*

Millet

	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku	Average Region
Land Preparation (MD[1])	10	10	10	8	10	7	4	8
Planting	3	3	3	3	3	3	2	3
Thinning/Weeding	10	10	10	10	10	8	8	9
Harvesting	6	6	6	6	6	5	5	6
Threshing/Grading	4	4	3	3	4	3	3	3
Total Labour (MD)	33	33	32	30	33	26	22	30
Total Labour Cost ¢	132.00	132.00	128.00	120.00	132.00	104.00	88.00	120.00
Cost of Seed[2] ¢	3.60	3.60	3.80	3.60	3.80	3.60	3.60	3.60
Cost of Machinery/Animal Power Services ¢	-	-	-	-	-	8.00	24.00	-
Total Non-Labour Cost ¢	3.60	3.60	3.80	3.60	3.80	11.60	27.60	3.60
Yield (lb)	550	550	630	620	620	635	635	610
Gross Returns ¢	198.00	198.00	214.20	229.40	204.60	228.60	228.60	213.50
Net Returns ¢	62.40	62.40	82.4	105.80	68.80	113.00	113.00	89.90
Gross Margins ¢	194.40	194.40	210.40	225.80	200.80	217.00	201.00	209.90
Return Per Man-Day of Labour ¢	5.89	5.89	6.57	7.52	6.08	8.34	9.13	6.99

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* Compiled from Survey Data.

[1] Man-days Per Acre.

[2] For Seed Rate of 10 Lbs Per Acre.

Appendix Table 8:2

Sorghum

	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku	Average Region
Land Preparation (MD)	10	10	10	8	10	7	4	8
Planting	3	3	3	3	3	3	2	3
Thinning/Weeding	10	10	10	10	10	8	8	9
Harvesting	6	6	6	6	6	5	5	6
Threshing/Grading	4	4	3	3	4	3	3	3
Total Labour (MD)	33	33	32	30	33	26	22	30
Total Labour Cost ¢	132.00	132.00	128.00	120.00	132.00	104.00	88.00	120.00
Cost of Seed ¢	3.50	3.50	3.60	3.50	3.60	3.50	3.50	3.50
Cost of Machinery/Animal Power Services ¢	-	-	-	-	-	8.00	24.00	-
Total Non-Labour Cost ¢	3.50	3.50	3.60	3.50	3.60	11.50	27.50	3.50
Yields (LBS)	600	600	570	570	550	550	570	580
Gross Returns ¢	174.00	174.00	171.00	199.50	176.00	176.00	176.70	179.80
Net Returns ¢	38.50	38.50	39.40	76.00	40.40	60.50	61.20	56.30
Gross Margins ¢	170.50	170.50	167.40	196.00	172.40	164.50	149.20	176.30
Returns Per Man-days of Labour ¢	5.16	5.16	5.23	6.53	5.22	6.32	6.78	5.87

Appendix Table 8:3

Cowpea

	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku	Average Region
Land Preparation (MD)	10	10	10	8	10	7	4	8
Planting	2	2	2	2	2	2	2	2
Weeding	10	10	8	8	8	8	8	9
Harvesting	4	4	3	3	3	4	4	4
Dehusking/Grading	2	2	2	2	2	2	2	2
Total Labour (MD)	28	28	25	23	25	23	20	25
Total Labour Cost ¢	112.00	112.00	100.00	92.00	100.00	92.00	80.00	100.00
Cost of Seed ¢	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Cost of Machinery/Animal Power Services ¢	-	-	-	-	-	8.00	24.00	-
Total Non-Labour Cost ¢	4.00	4.00	4.00	4.00	4.00	12.00	28.00	4.00
Yi Yield (lbs)	300	320	250	270	270	320	320	290
Gross Returns ¢	90.00	96.00	70.00	75.60	70.20	108.80	102.40	87.00
Net Returns ¢	-26.00	-20.00	-34.00	-20.40	-33.80	4.80	-5.60	17.00
Gross Margins ¢	86.00	92.00	66.00	71.60	66.20	80.00	52.00	83.50
Returns per Man-day of Labour ¢	3.07	3.28	2.64	3.11	2.64	3.47	2.60	3.32

Appendix Table 8:4

Groundnut

	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku	Average Region
Land Prepartion (MD)	11	10	10	10	11	9	5	9
Planting	4	3	4	4	3	3	3	3
Weeding	10	10	8	8	8	8	8	9
Harvesting	8	8	8	8	8	9	9	8
Dehusking	6	6	7	7	6	7	7	7
Total Labour	39	37	37	37	36	36	32	36
Total Labour Cost ¢	150.00	148.00	148.00	148.00	144.00	144.00	128.00	144.00
Cost of Seed ¢	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
Cost of Machinery/ Animal Power Services ¢	-	-	-	-	-	8.0	24.00	-
Total Non-Labour Costs ¢	24.00	24.00	24.00	24.00	24.00	32.00	48.00	24.00
Yield (lbs)	480	480	500	500	660	600	660	550
Gross Returns ¢	254.40	254.40	245.00	250.00	316.80	306.00	323.40	277.35
Net Return ¢	80.40	82.40	73.00	78.00	148.00	130.00	147.40	109.35
Gross Margin ¢	230.40	230.40	221.00	226.00	292.80	274.00	275.40	253.35
Return Per Man-day of Labour ¢	5.90	6.22	5.97	6.10	8.13	7.61	8.60	7.60

Appendix Table 8:5

Rice

	Wa and Lawra	Sandama
Land Prepartion (MD)	12	11
Planting	3	3
Thinning/Weeding	12	14
Harvesting	8	8
Threshing	7	6
Total Labour	42	42
Total Labour Cost ¢	168.00	168.00
Cost of Seed ¢	15.00	15.00
Cost of Machinery/Animal Power Services ¢	-	-
Total Non-Labour Cost ¢	15.00	15.00
Yield (Lb Paddy)	750	750
Gross Returns ¢	180.00	180.00
Net Returns ¢	-3.00	-3.00
Gross Margin ¢	165.00	165.00
Returns Per Man-day of Labour ¢	3.92	3.92

Appendix Table 8:6
Maize

	Wa	Lawra
Land Preparation (MD)	10	10
Planting	3	3
Thinning/Weeding	10	10
Harvesting	7	7
Threshing	3	3
Total Labour (MD)	33	33
Total Labour Cost ¢	132.00	132.00
Cost of Seed	3.00	3.00
Cost of Machinery/Animal Power Services ¢	-	-
Total Non-Labour Cost ¢	3.00	3.00
Yield (LBS)	620	620
Gross Returns ¢	130.20	130.20
Net Returns ¢	-4.80	-4.80
Gross Margin ¢	127.20	127..20
Returns Per Man-day of labour ¢	3.85	3,85

Appendix Table 8:7

Yam

	Wa	Lawra
Land Preparation (MD)	20	20
Planting	6	6
Thinning/Weeding	18	18
Harvesting	15	15
Threshing	-	-
Total Labour (MD)	59	59
Total Labour Cost ¢	236.00	236.00
Cost of Seed	132.00	132.00
Cost of Machinery/Animal Power Services ¢	-	-
Total Non-Labour Cost ¢	132.00	132.00
Yield (LBS)	3000	3000
Gross Returns ¢	660.00	660.00
Net Returns ¢	292.00	292.00
Gross Margin ¢	528.00	528.00
Returns Per Man-day of Labour ¢	8.94	8.94

Appendix Table 8.8

EM-LM-S-COW-MA[1]

	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatango	Bawku
Land Prepartion (MD)	10	10	10	8	10	7	4
Planting	4	4	3	4	3	3	3
Thinning/Weeding	14	14	12	14	12	10	10
Harvesting	6	6	7	6	6	7	7
Threshing/Grading	4	4	3	3	4	4	3
Total Labour (MD)	38	38	35	35	35	31	27
Total Labour Cost ¢	152.00	152.00	140.00	140.00	140.00	124.00	108.00
Cost of Seed ¢	4.00	4.00	4.00	5.00	5.00	5.00	5.00
Cost of Machinery/Animal Power Services ¢	-	-	-	-	-	8.00	24.00
Total Non-Labour Cost ¢	4.00	4.00	5.00	5.00	5.00	13.00	29.00
Acreage Yield (LBS)	-	-	-	100	260	270	270
EM	-	-	-	100	260	270	270
LM	280	280	220	140	320	310	320
S	360	360	250	200	150	240	240
COW	80	70	70	90	100	150	150
MA	300	300	-	-	-	-	-
Gross Returns ¢	292.20	289.20	169.40	184.00	265.40	336.60	334.80
Net Returns ¢	136.00	133.20	24.40	39.00	120.40	199.60	197.80
Gross Margins ¢	288.20	285.20	164.40	179.00	260.40	323.60	305.80
Returns Per Man-day of Labour ¢	7.58	7.50	4.69	5.11	7.44	10.43	11.32

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1. EM = Early Millet LM = Late Millet S = Sorghum COW = Cowpea MA = Maize

Appendix Table 8:9

LM-S-COW-MA

	Wa	Lawra
Land Prepartion (MD)	10	10
Planting (MD)	4	4
Thinning/Weeding (MD)	14	14
Harvesting (MD)	6	6
Threshing/Grading (MD)	4	4
Total Labour (MD)	38	38
Total Labour Costs ¢	152.00	152.00
Cost of Seed ¢	5.00	5.00
Cost of Machinery/Animal Power Services ¢	-	-
Total Non-Labour Costs ¢	5.00	5.00
Average Yield (LBS)		
MA	300	300
LM	270	270
S	310	310
COW	-	-
Gross Returns ¢	250.10	250.10
Net Returns ¢	93.10	93.10
Gross Margins ¢	245.10	245.10
Returns Per Man-day of Labour ¢	6.45	6.45

Appendix Table 8:10

GN-BAM[1]

	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku	Average Region
Land Prepartion (MD)	11	10	10	10	11	9	5	9
Planting	4	4	3	4	4	4	4	4
Thinning/Weeding	10	10	8	8	8	8	8	9
Harvesting	10	10	10	9	10	10	10	10
Threshing/Grading	6	6	7	6	6	7	7	6
Total Labour (MD)	41	40	38	37	39	38	34	38
Total Labour Costs ¢	164.00	160.00	152.00	148.00	156.00	152.00	136.00	152.00
Cost of Seed ¢	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00
Cost of Machinery/Animal Power Services ¢	-	-	-	-	-	8.00	24.00	-
Total Non-Labour Costs ¢	29.00	29.00	29.00	29.00	29.00	37.00	53.00	29.00
Average Yield (LBS)	280	280	320	420	360	350	360	330
GN	280	280	320	420	360	350	360	330
BAM	250	250	180	180	170	240	240	210
Gross Returns ¢	253.40	253.40	232.40	280.20	240.80	276.90	272.40	252.00
Net Returns ¢	60.40	64.40	51.40	103.20	55.80	87.90	83.40	71.00
Gross Margins ¢	224.40	224.40	203.40	251.20	211.80	239.90	219.40	223.00
Returns Per Man-day of Labour ¢	5.47	5.61	5.35	6.78	5.43	6.31	6.45	5.86

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[1] GN = Groundnuts BAM = Bambara Beans

Appendix Table 8:11

MA-S-LM-COW

	WA	LAWRA	TUMU	NAURONGO	BAWRU
Land Preparation (MD)	10	10	10	10	4
Planting	4	4	3	3	3
Weeding/Thinning	14	14	12	12	10
Harvesting	6	6	7	6	7
Threshing/Grading	4	4	3	4	3
Total Labour	38	38	35	35	27
Total Labour Costs ¢	152.00	152.00	140.00	140.00	108.00
Cost of Seeds ¢	7.00	7.00	5.00	5.00	5.00
Cost of Machinery/Animal Power Services ¢	-	-	-	-	24.00
Total Non-Labour Costs ¢	7.00	7.00	5.00	5.00	29.00
Average Yields (LBS)	340	420	-	-	-
MA	340	420	-	-	-
S	430	410	250	240	-
LM	-	-	220	380	400
COW	-	-	70	150	220
Gross Returns ¢	196.10	207.10	169.40	241.20	214.40
Net Returns ¢	39.10	48.10	24.40	96.20	77.40
Gross Margins ¢	189.10	200.10	164.40	236.20	185.40
Returns Per Man-day of Labour ¢	4.97	5.26	4.69	6.74	6.86

Appendix Table 9*

Acreage and Price Data Used in Supply Response Analysis

Year	Acres of Cowpea ('000)	Av. Price per Bag of Cowpea ¢	Av. Price per Bag of Groundnut ¢	Av. Price per Bag of Millet ¢	Av. Total Rainfall Jan. - May (inches)	Acres of[1] Groundnut ('000)	Consumer Price Index (National)
1963	160	10.65	10.68	9.14	11.19	83	109.1
1964	126	12.40	13.03	12.40	6.14	84	119.7
1965	119	18.21	18.80	12.59	5.83	91	151.3
1966	91	17.88	15.19	13.60	8.87	91	171.4
1967	42	13.15	12.75	10.53	8.89	63	157.0
1968	62	14.96	16.46	10.05	11.30	90	169.7
1969	158	18.45	18.29	14.85	6.20	96	181.8
1970	277	19.61	18.40	15.95	5.69	157	188.5
1971	277	22.58	18.50	14.73	6.76	159	206.0
1972	198	26.70	19.27	18.22	7.05	129	226.7
1973	144	31.68	30.37	24.36	8.23	66	266.4
1974	251	49.52	40.75	28.37	5.22	130	314.3
1975	267	49.13	47.52	27.05	8.28	105	408.9
1976	204	74.21	88.80	71.72	7.20	110	639.3
1977	184	144.97	190.36	150.15	6.79	97	1382.5

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*Compiled from the Annual Reports of the Ministry of Agriculture and the Central Bureau of Statistics and the Meterological Department. All data refer to the Upper Region except the CPI.

[1] Used as Instrumental Variable for Acreage of Cowpea.

Appendix Table 10*

Average Farm-gate Prices of Produce by District (¢ per lb)

Produce	Wa	Lawra	Tumu	Sandama	Navrongo	Bolgatanga	Bawku
Millet	0.36	0.36	0.34	0.37	0.33	0.36	0.36
Sorghum	0.29	0.29	0.30	0.35	0.32	0.32	0.31
Cowpea	0.30	0.30	0.28	0.28	0.26	0.34	0.32
Groundnut	0.53	0.53	0.49	0.50	0.48	0.51	0.49
Bambara	0.42	0.42	0.42	0.39	0.40	0.41	0.40
Rice	0.24	0.24	0.32	0.24	0.32	0.32	0.32
Maize	0.21	0.21	-	-	-	-	-
Yam	0.22	0.22	-	-	-	-	-

*Compiled from Survey Data.

Appendix Table 11

Shadow Prices of Resources in Optimum Profit Plan I by District

	Total Supply Level	Used	Unused	Shadow Price	Range of Resource Shadow Price is Valid Lower	Upper
1. Wa						
Land	9.3	9.3	0.0	¢196.48	8.94	10.70
M-AFL (MDS)	172	173	-0.0	¢ 4.00	-.0	198.0
M-JFL	172	187.1	-15.1	0.0		
J-AFL	172	130.4	41.6	0.0		
PTOCTFL	172	88.9	83.1	0.0		
N-DFL	172	187.1	-15.1	0.0		
OPCAP	¢440	440.0	0.0	¢2.72	¢255.02	¢487.03
BORCAP	¢440	440.0	0.0	¢2.57	¢255.02	¢487.03
2. Tumu						
Land	17.1	17.1	0.0	¢205.00	16.0	21.0
M-AFL	160.0	0.0	160.0	0.0		
M-JFL	160.0	57.4	102.6	0.0		
J-AFL	160.0	125.8	34.2	0.0		
PTOCTFL	160.0	125.8	34.2	0.0		
N-DFL	160.0	108.7	51.3	0.0		
OPCAP	¢420.0	¢342.0	¢ 78.0	0.0		
BORCAP	¢420.0	0.0	¢420.0	0.0		
3. Sandana						
Land	4.0	4.0	0.0	¢280.20	1.38	11.11
M-AFL	168.0	40.0	128.0	0.0		
M-JFL	168.0	16.0	152.0	0.0		
J-AFL	168.0	32.0	136.0	0.0		
PTOCTFL	168.0	36.0	132.0	0.0		
N-DFL	168.0	34.0	144.0	0.0		
OPCAP	¢300.0	¢108.0	¢192.0	0.0		
OPCAP	¢300.0	¢108.0	¢192.0	0.0		
BORCAP	¢300.0	¢ 0.0	¢300.0	0.0		
4. Navrongo						
Land	4.0	4.0	0.0	¢316.80	0.67	6.0
M-AFL	124.0	44.0	80.0			
M-JFL	124.0	12.0	112.0			
J-AFL	124.0	32.0	92.0			
PTOCTFL	124.0	40.0	84.0			
N-DFL	124.0	16.0	108.0			
OPCAP	¢120.0	¢80.0	¢40.0			
BORCAP	¢120.0	0.0	¢120.0			
5. Bolgatanga						
Land	2.2	2.2	0.0	¢336.60	0.0	2.29
M-AFL	168.0	15.4	152.6			
M-JFL	168.0	6.6	161.4			
J-AFL	168.0	22.0	146.0			
PTOCTFL	168.0	8.8	159.2			
N-DFL	168.0	15.4	152.6			
OPCAP	¢230.0	¢ 46.2	¢183.80			
BORCAP	¢230.0	¢ 0.0	¢230.00			
6. Bawku						
Land	8.0	8.0	0.0	¢334.80	7.15	20.20
M-AFL	202.0	32.0	0.0			
M-JFL	202.0	24.0	0.0			
J-AFL	202.0	80.0	0.0			
PTOCTFL	202.0	24.0	0.0			
N-DFL	202.0	56.0	0.0			
OPCAP	¢220.0	¢40.0	¢180.0			
BORCAP	¢220.0	0.0	¢220.0			

Appendix Table 12

Variance - Covariance Matrix For Representative Farms - Wa and Lawra Districts

	S-Ma-M	S-Ma	Yam	Bam-Gn	Ma	Cow	M	S	R	M-S-Cow-Ma	Gn
S-Ma-M	272.9	121.1	813.0	611.3	149.6	108.8	247.3	236.0	280.4	265.4	795.0
S-Ma	121.1	439.3	944.0	379.2	58.4	63.4	144.1	180.5	212.5	228.3	468.8
Yam	813.0	944.0	13502.4	783.8	520.4	104.3	249.7	1244.0	3129.1	661.2	3306.0
Bam-Gn	611.3	3792.0	782.8	3760.1	250.8	367.7	830.8	993.5	804.4	866.2	4954.5
Ma	149.6	58.4	520.4	250.8	116.6	27.5	61.8	107.1	176.6	30.6	564.2
Cow	108.8	63.4	104.3	367.7	27.5	62.6	141.4	132.5	90.1	136.1	418.0
M	247.3	144.1	249.7	830.8	61.8	141.4	318.6	296.8	201.0	307.0	931.0
S	236.0	180.5	1244.0	993.5	107.1	132.5	296.8	500.0	469.2	391.8	1164.5
R	280.4	212.5	3129.1	804.4	176.6	90.1	201.0	469.2	1038.8	255.7	1522.6
M-S-Cow-Ma	265.4	228.3	661.2	866.3	30.6	136.1	307.0	391.8	255.0	387.7	891.1
Gn	795.0	468.8	3306.0	4954.5	564.2	418.0	931.0	1164.5	1522.6	891.7	10277.9

Appendix Table 13

Variance-Covariance Matrix for Representative Farm Tumu District

	S-M-Cow	Gn-Bam	M	S	Cow	Gn
S-M-Cow	755.8	817.6	286.3	400.5	119.4	620.2
Gn-Bam	817.6	6870.2	750.0	983.2	313.1	3345.5
M	286.3	750.0	568.5	290.2	118.4	620.5
S	400.5	983.2	290.2	1071.8	121.9	850.6
Cow	119.4	313.1	118.4	121.9	98.8	262.1
Gn	620.2	3345.5	620.5	850.6	262.1	10233.1

Appendix Table 14

Variance-Covariance Matrix for Representative Farm - Sandama District

	S-M-Cow	M	S	Gn	R	Cow	Gn-Bam
S-M-Cow	433.1	333.4	498.8	673.9	268.4	130.2	858.2
M	333.4	336.3	367.2	685.1	206.4	128.8	800.0
S	498.8	367.2	725.2	1004.4	565.4	141.8	1176.2
Gn	673.9	685.1	1004.4	5272.2	1217.7	266.0	3330.0
R	268.4	206.4	565.4	1217.7	1040.0	79.4	759.1
Cow	130.2	128.8	141.8	266.0	79.4	49.4	307.1
Gn-Bam	858.2	800.0	1176.2	3330.0	759.9	307.1	3302.8

Appendix Table 15

Variance-Covariance Matrix for Representative Farm - Navrongo District

	M	S	Gn	Cow	E-Lm-S-Cow	Gn-Bam	Lm-S-Cow
M	317.9	330.6	607.5	116.3	367.2	140.1	403.8
S	330.6	622.0	852.3	122.0	523.4	77.6	575.6
Gn	601.5	852.3	4299.4	223.2	689.6	541.6	629.1
Cow	116.3	122.0	2232.2	42.6	134.6	51.4	148.0
E-Lm-S-Cow	367.2	523.4	689.6	134.6	556.0	175.1	338.1
Gn-Bam	140.1	77.6	541.6	51.4	175.1	197.1	192.6
Lm-S-Cow	403.8	575.6	629.1	148.0	338.1	192.6	672.4

Appendix Table 16

Variance-Covariance Matrix for Representative Farm - Bolgatanga District

	M	S	Gn	Cow	M-S-Cow	Gn-Bam	M-Cow
M	639.2	896.1	683.9	249.2	394.9	804.3	804.4
S	896.1	9118.0	2620.7	706.5	1522.2	2904.2	3100.2
Gn	683.9	2620.7	11091.6	542.2	841.3	3527.6	1713.5
Cow	249.2	706.5	542.2	390.4	309.3	630.2	639.9
M-S-Cow	394.9	1522.2	841.3	309.3	1293.2	1079.0	722.6
Gn-Bam	804.3	2904.2	3527.6	630.2	1079.0	7047.2	2197.6
M-Cow	804.4	3100.2	1713.5	639.9	722.6	2197.6	5323.0

Appendix Table 17

Variance-Covariance Matrix for Representative Farm for Bawku District

	M	S	Gn	Cow	S-M-Cow	Gn-Bam	M-Cow
M	318.6	317.5	657.1	143.4	335.5	777.8	270.7
S	317.5	572.2	892.0	144.0	458.1	994.9	369.6
Gn	657.1	892.0	5119.4	299.8	686.7	3277.4	554.0
Cow	143.4	144.0	299.8	64.6	151.2	350.7	122.0
S-M-Cow	335.5	458.1	686.7	151.2	463.1	886.4	206.6
Gn-Bam	777.8	994.9	3277.4	350.7	886.4	3294.8	715.1
M-Cow	270.7	369.6	554.0	122.0	206.6	715.1	301.4

OPTIMUM (FARM) STRATEGIES UPPER REGION - FARMERS QUESTIONNAIRE (Part 1)

A. FAMILY INFORMATION

1. Name ______________________ 2. Village ______________

3. Age ______________ 4. Education: No formal education ______________

Primary School __________ Middle Sch __________ Above Mid Sch ______________

5. Non-Farm Occupation ______________________________

6. Income from Non-Farm Sources ______________________________

7. Family Size ______________

8. Native of Area ______________ Immigrant Farmer ______________

B. FARMING RESOURCES

a)

Equipment	No.	Year Acquired	Price	Estimate Life	Remarks
Tractor					
Bullocks					
Ploughs					
Hoe					
Machet					
Baskets					
Sacks					

b) Financing 1978

Source	Amount	Interest	Repayment Terms
Own sources			
Bank credit			
Private lender			
Family member			

Comments on financing problems ____________________

____

c) Livestock

Type	Herd Size	Av. Age	Value Est.	Ave. Culled/yr.	Value of culled
Cattle					
Sheep					
Goat					
Pigs					
Poultry					
Others					

d) Labour

Household members providing free farm labour

Age	No.	Males Type of Operations	No.	Females Type of Operations
10 - 14				
15 - 20				
21 - 44				
45 - 54				
55 - 64				
65 and over				

1. Do you use any hired labour Yes ______ No ______

If yes, indicate operations it is used for:

land preparation ☐ sowing ☐ weeding ☐

Fertilizer application ☐ Harvesting ☐

2. Give payment for hired labour; wage rate ☐

Kind of payment ☐ Type ☐ Value ☐

3. Specify problems with hired labour

Scarcity ☐ High Wage ☐ Others ______

e) Land

1. Total land available to you ______

2. Indicate problems of acquiring more land if any ______

3. Give utilization of available land this year ☐

1977 ☐ 1976 ☐ 1975 ☐

and reasons for differences if any ______

4. Specify problems with your land: low fertility ☐

Tenancy ☐ Low Rainfall ☐ Distance from Village ☐

Others ______

C. 1. Indicate crops grown in order of importance to you and reasons

Crop	Reason for Importance
i	
ii	
iii	
iv	
v	
vi	
vii	

2. Estimate yields/acre for your crops for previous years.

Crops	1977	1976	1975	1974	1973

D. CROPPING ACTIVITIES

Utilization 1978

	Holding	Field	Acres	Crop	Production	Crop Last Year	Special Remarks
Farm One	Owned						
	Rented						
	Terms						
	Duration						
	Shared rent						
	Total						

Repeat for Farm 2, Farm 3, Farm 4, etc., if any.

E. COWPEA INFORMATION

1. When did you start growing cowpea? ____________________

2. What varities of cowpea do you produce?

   a) ____________ b) ____________ c) ____________

   Give reasons ______________________________________

3. Give acreage of cowpea produced last year ☐

   1976 ☐ 1975 ☐ 1974 ☐

4. Give the quantities of cowpea harvested last year ☐

   1976 ☐ 1975 ☐ 1974 ☐

5. Why do you grown cowpea: a) for food ☐

   b) Silage ☐ c) Soil Enrichment ☐ d) Cash ☐

   e) Others specify ______________________________

6. Why do you not grow more cowpea? ______________________

7. What special problems do you encounter in cowpea cultivation; indicate in order of seriousness.

   a) poor seed ☐ b) Field pests ☐

   c) storage problems ☐ d) unreliable rainfall ☐

   e) poor soil ☐ f) low prices ☐

   g) Unstable price ☐ h) yield variability ☐

8. What would you want to see done to promote cowpea production? ____

   ____

(Part 2) LABOUR/MACHINERY INPUTS

	Gang Size Per Acre	No. of Days Per Gang	No. of Hours Per Day/Acre	Total Hours (1x2x3)	No. of Man Working Days (4/8 Hrs)	Cost Per Man Day	Total Labour Cost (5x6)	Cost of Machinery Per Day	Total Labour and Machinery Cost (7 + 8)
	1	2	3	4	5	6	7	8	9
LAND CLEARING, BURNING AND PREPARATION									
Tobacco									
Cotton									
Groundnuts									
Vegetables									
Fibre									
Others (State)									
SOWING/PLANTING									
Tobacco									
Cotton									
Groundnuts									
Vegetables									
Fibre									
Others (State)									
WEEDING, SPRAYING AND FERTILIZING									
Tobacco									
Cotton									
Groundnuts									
Vegetables									
Fibre									
Others (State)									
HARVESTING									
Tobacco									
Cotton									
Groundnuts									
Vegetables									
Fibre									
Others (State)									

LABOUR/MACHINE INPUTS

	Gang Size Per Acre	No. of Days Per Gang Per/Acre	No. of Hours Per Day/ Gang	Total Hours (1x2x3)	No. of Man Working days (4/6)	Cost Per Man/Day	Total Labour Cost (5x6)	Cost of Machinery Per day	Total Labour and Machinery Cost (7 + 8)
	1	2	3	4	5	6	7	8	9
LAND CLEARING, BURNING AND PREPARATION									
Maize									
Millet Early									
Millet Late									
Guinea Corn									
Rice									
Bambara Beans									
SOWING/PLANTING									
Maize									
Millet Early									
Millet Late									
Guinea Corn									
Rice									
Bambara Benas									
WEEDING, SPRAYING AND FERTILIZING									
Maize									
Millet Early									
Millet Late									
Guinea Corn									
Rice									
Bambara Beans									
HARVESTING									
Maize									
Millet Early									
Millet Late									
Guinea Corn									
Rice									
Bambara Beans									

NOTE: (i) Make separate entries for all crops from each farm (give farm numbers) (ii) State whether data is for pure, mixed major or mixed minor cover

HOLDING NO: LABOUR AND CAPITAL INPUTS

FIELD	ACRES	LAND PREP.	SEEDS		SOWING	WEEDING		FERTILIZER		INSECTICIDES		HARVESTING	OTHERS	YIELD
			lb	¢		1st	2nd	QUANTITY	VALUE	QUANTITY	VALUE			
UNUSED LAND														
TOTAL ACRES														